Proposed
Risk Management Guidance for the Permitting of New Stationary Diesel-Fueled Engines

California Environmental Protection Agency

Air Resources Board

Stationary Source Division
Emission Assessment Branch

February 9, 2000
(DRAFT)

Guidance Prepared By:

Alexander J. Santos

Contributing Authors:

Robert Hughes
Grant Chin
Lisa Jennings
Glen Villa
Lisa Williams
Ron Hand
Peggy Jenkins
Robert Krieger
Melanie Marty
Tony Servin
Louis Chiu
Angus McPherson

Reviewed and Approved By:

Peter D. Venturini, Chief, Stationary Source Division
Donald J. Ames, Assistant Chief, Stationary Source Division
Daniel E. Donohoue, Chief, Emission Assessment Branch

Acknowledgements:

In appreciation of their participation in developing this guidance, the Air Resources Board staff extends their thanks to the Risk Management Subcommittee.

TABLE OF CONTENTS

		Page
I.	Overview…………………………………………………………………………	4
II.	Applicability………………………………………………………………………	7
III.	Background………………………………………………………………………	8
IV.	Key Terms………………………………………………………………………..	9
V.	The Basic Approach………………………………………………………………..	10
VI.	Permitting Requirements……………………………………………………….….	11
VII.	Approval Process……………………………………………………………….	18
VIII.	Diesel-Specific Adjustment to the Existing Risk Assessment Methodology…………………………………………………………………….	24
IX.	Discussion of the Uncertainty Associated with Risk Assessment…………	28
X.	References………………………………………………………………………	32

Appendix I:	Draft Diesel Oxidation Catalysts and Catalyzed Diesel Particulate Filter Control Technology Evaluations……………..........	33
Appendix 2:	Potential Cancer Risk Associated with the Air Dispersion Modeling Results…………………………………………	48
Appendix 3:	Draft Sierra Nevada Brewery Source Test Protocol………….....…..	61

I. Overview

A. What is the purpose of this document?

This document is the Air Resources Board (ARB/Board) staff's proposed guidance to assist local air pollution control districts and air quality management districts (districts) in making risk management decisions associated with the permitting of new stationary diesel-fueled engines. This guidance identifies minimum technology requirements for reducing particulate matter emissions from new stationary diesel-fueled engines. It identifies engines that may be approved without a site-specific health risk assessment (HRA) provided the minimum technology requirements are met. It also discusses diesel-specific adjustments that may be used when performing a site-specific HRA for a diesel-fueled engine.

B. How does the guidance presented in this document differ from the guidance presented in the ARB's Risk Management Guidelines for New and Modified Sources of Toxic Air Pollutants (Guidelines), July 1993?

The 1993 Guidelines suggest the use of a combination of specific risk levels and a risk action range to evaluate new and modified sources of toxic air pollutants. Specific risk levels are suggested for triggering the installation of toxic best available control technology (T-BACT) and for establishing an upper level maximum risk. A risk action range is suggested for providing flexibility when considering, in addition to risk, other factors such as site-specific meteorology, the proximity to residences, and potential impact on sensitive receptors. A discussion of these factors would be provided in a Specific Findings Report. The Air Pollution Control Officer (APCO) would review this report and prepare findings supporting a decision to approve or deny the permit to operate.

The guidance presented in this document defines a technology-based approach that retains a risk-based review under certain special conditions. The guidance suggests technology-based requirements for all new stationary diesel-fueled engines. The first technology level requires the use of engines certified to the most stringent standards for particulate emissions. The second level requires the use of engines certified to the most stringent standards for particulate emissions coupled with the best available add-on controls for particulate emissions. For most engines, the permit to operate the engine would then be approvable simply by meeting the appropriate technology requirement, eliminating the need for a site-specific HRA. The third level would apply to a small group of engines. Because of site-specific (e.g., located near school) or equipment-specific factors (e.g., hours of operation), a site-specific HRA would need to be performed prior to approval. A discussion of the results of the HRA, as well as other factors, would be provided in a Specific Findings Report prepared by either the source or the district. The public would then have an opportunity to review the Specific Findings Report and the proposed permitting action. The APCO would review the Specific Findings Report and the public's comments and prepare findings supporting a decision to approve or deny the permit to operate.

C. What are the key recommendations in this guidance?

The key recommendations in this guidance are:

- Approve permits for Tier 1 diesel-fueled engines if they meet the appropriate minimum technology requirements (see Table 1). Most (90%) new stationary diesel-fueled engines meeting appropriate minimum technology requirements will result in the lowest achievable risk levels, in consideration of costs, uncertainty in the emissions and exposure estimates, and uncertainties in the approved health values. For these engines, we do not believe site-specific HRA is necessary.

- Require a site-specific risk analysis prior to approval of diesel-fueled engines that fall within the Tier 2 category (see Table 1). For some (less than 10%) new stationary diesel-fueled engines, a site-specific HRA is needed to ensure that the lowest achievable risk levels will be achieved in consideration of costs, uncertainty in the emissions and exposure estimates, and uncertainties in the approved health values. For these sources, we believe a site-specific risk analysis needs to be completed prior to making a permitting decision. This approach is very similar to the action range approach presented in the 1993 Guidelines, where risks as well as other factors, such as location of sensitive receptors, are considered by the APCO prior to making a permitting decision. The significant difference between the approach in this guidance and the approach in the 1993 Guidelines is the lack of an upper level permit denial risk value. Rather than automatically denying any source with a risk greater than the upper level, we suggest the public be provided an opportunity to review and comment on the proposed permit action. The APCO would consider the public's comments in making the final permitting decision. We believe an upper level risk level would be too restrictive, not allowing for the approval of sources with well-controlled diesel-fueled engines that perform critical functions (i.e., emergency power generation) or for which there is no economically or technically feasible substitute.

- For Tier 2 engines, conduct risk assessments consistent with the *California Air Pollution Control Officers Association (CAPCOA), Air Toxics "Hot Spots" Program, Revised 1992 Risk Assessment Guidelines* (Risk Assessment Guidelines), dated October 1993[1], and

[1] The Office of Environmental Health Hazard Assessment (OEHHA) is currently revising the CAPCOA Risk Assessment Guidelines. It is expected that districts will use the OEHHA risk assessment guidelines when completed later this year (2000).

the diesel-specific risk assessment guidance presented in Section VIII of this document. Use particulate matter as a surrogate for all toxic air contaminant emissions from diesel-fueled engines when determining the cancer risk and the noncancer hazard index for the inhalation pathway.

- Estimate risk using the Scientific Review Panel's (SRP) recommended unit risk factor of 3×10^{-4} chances of cancer per microgram per cubic meter of diesel particulate matter [$3 \times 10^{-4} (\mu g/m^3)^{-1}$] based on 70 years of exposure.[2]

- Consider the uncertainty in the risk assessment information when making risk management decisions.

E. What is the statutory basis for developing this guidance?

The statutory authority for the ARB to develop this guidance document is found in Health and Safety Code (H&SC) sections 39605 and 39620(a). Section 39605 states that the ARB may provide assistance to any district. Section 39620(a) states that the ARB shall implement a program to assist districts in implementing permits. This guidance provides assistance to districts for permitting new stationary diesel-fueled engines and is part of the ARB's program to assist districts in implementing permits. Further, the general authority for districts to control air pollution from all sources, other than emissions from motor vehicles, is found in H&SC section 40000.

This guidance document references the Risk Assessment Guidelines when defining how site-specific risk assessments should be conducted. However, the statutory authorities associated with the "Hot Spots" program, H&SC sections 44300 through 44394, should not be considered applicable to the implementation of this guidance.

For example, H&SC section 44360(b) allows for the operator of a facility to bring in new information to a district concerning the scientific basis for selecting risk values. However, consideration of new risk value information is not part of this guidance development process. This guidance document is being developed under the Assembly Bill (AB) 1807 process. The statutory requirements for the AB 1807 process are found in H&SC sections 39650 through 39674. Under the AB 1807 process, new information regarding the risk value of particulate matter from diesel-fueled engines needs to be reviewed and evaluated by the Office of Environmental Health Hazard Assessment (OEHHA) and the SRP as part of the existing AB 1807 toxic air contaminant identification process.

[2] For Tier 2 engines, the Specific Findings Report should also report the full range of risk identified by the SRP; 1.3×10^{-4} to 2.4×10^{-3} chances per microgram per cubic meter of diesel particulate matter. The unit risk factor of $3 \times 10^{-4} (\mu g/m^3)^{-1}$ is commonly expressed as 300 chances per microgram per meter cubed of diesel particulate matter.

II. Applicability

This section discusses the types of engines and fuels addressed by this guidance.

A. What types of diesel-fueled equipment are addressed by this guidance?

This guidance specifically addresses all new stationary (and some portable), compression-ignition, internal combustion engines designed to use diesel fuel. This guidance does not address: 1) mobile equipment, 2) portable equipment that is registered in the Statewide Registration Program or exempt from local regulation due to Federal law, 3) military tactical support equipment, and 4) stationary and portable agricultural engines.

Mobile equipment, on-road and off-road vehicles, are not addressed in this guidance because they are not stationary equipment and are not required to obtain district operating permits.

Portable engines are engines that are designed and capable of being carried or moved from one location to another and do not remain at a single location for more than 12 consecutive months. Portable engines are not required to obtain a district operating permit if they are registered in the Statewide Registration Program. Since they are not required to obtain an operating permit, these engines are not addressed by this guidance. Of the portable engines that are not registered, Federal regulations prohibits the state from establishing technology requirements for new portable engines that are used in construction or farm equipment and are less than 175 horsepower. Those portable engines that are not addressed by the state prohibition, engines greater than 175 horsepower and not used in construction or farm equipment, would be subject to this guidance.

Military tactical support equipment and stationary and portable agricultural equipment are exempted from permitting requirements through state law and are not addressed by this guidance.

In addition, we do not recommend using the health values contained in this guidance for assessing the risk from diesel-fueled equipment such as turbines, boilers, heaters, kilns, or flares.

B. Why are diesel-fueled turbines or external combustion engines <u>not</u> addressed in this guidance?

The health effects data used to develop the unit risk factor for diesel particulate matter is based on compression-ignition (diesel cycle) engines. Currently, there is insufficient information to determine if the toxicity of particulate emissions from diesel-fueled turbines or external combustion engines (boilers, heaters, kilns, or flares) is significantly different from the toxicity of particulate emissions from diesel-fueled compression-ignition engines. As a result, we do not recommend using the health values contained in this guidance for permitting diesel-fueled turbines or external combustion engines, at this time. We will continue to evaluate the appropriateness of excluding turbines and external combustion engines as more data become available.

C. Are stationary compression-ignition engines using jet fuel addressed in the guidance?

Yes. Stationary, compression-ignition engines using jet fuel should be treated the same as stationary, compression-ignition engines using diesel fuel. Jet fuel has properties very similar to diesel fuel (i.e., sulfur content, cetane number, T-90 temperature, and aromatic content). Jet fuel can be used in compression-ignition engines without any significant adjustments to the engine. Because of the similarity in fuel properties and the ease of fuel switching, we believe treating new stationary compression-ignition engines using jet fuel or diesel fuel the same is appropriate and necessary.

III. Background

A. What action has the ARB taken concerning the identification of emissions from diesel-fueled engines as toxic air contaminants?

In August 1998, the ARB identified particulate matter emissions from diesel-fueled engines as a toxic air contaminant with no threshold exposure level. The Board approved the SRP's cancer unit risk factor of 1.3×10^{-4} to 2.4×10^{-3} chances per microgram per cubic meter of diesel particulate matter (130 to 2400 chances per million per microgram per cubic meter of diesel particulate matter). Final approval of ARB's action by the Office of Administrative Law and the Secretary of State occurred in July 1999.

B. What are the uncertainties associated with the risk assessment?

The three main areas of uncertainty, which may underestimate or overestimate the risk from exposure to toxic air contaminants from diesel-fueled engines, are uncertainty in the emissions estimation techniques (emission factors and source test results); uncertainty in air dispersion modeling techniques used to assess exposure; and uncertainty in the techniques used to determine health risk values (cancer unit risk factor and the noncancer reference exposure level.) The uncertainties in the emissions estimation techniques and in air dispersion modeling techniques are well known and discussed in numerous publications. The uncertainty in the techniques used to determine health risk values is discussed in more detail in Section IX. Section IX contains excerpts from the Risk Assessment Guidelines and the *Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Appendix III, Part B, Health Risk Assessment for Diesel Exhaust.*

IV. Key Terms

A. **Diesel Fuel:** Fuel meeting the following specification

ASTM D975 – 98, Standard Specification for Diesel Fuel Oils; includes No. 1-D, No. 1-D low sulfur, No. 2-D, No. 2-D low sulfur, and No. 4-D.

B. **Jet Fuel:** Fuel meeting the following specification

ASTM D 1655 – 98, Standard Specification for Aviation Turbine Fuels; includes Jet A, Jet A-1, and Jet B.

MIL-DTL-5624T, Turbine Fuel, Aviation, Grades JP-4, JP-5, and JP-5/JP8 ST.

MIL-T-83133D, Turbine Fuel, Aviation, Kerosene Types, NATO F-34 (JP-8) and NATO F-35; NATO F-35 similar to (JP-8).

C. **Diesel-Fueled Engine:** For purposes of this guidance, any internal combustion, compression-ignition (diesel cycle) engine that is fueled by diesel fuel or jet fuel.

D. **Emergency Standby Engine:** An internal combustion engine used only as follows: 1) when normal power line or natural gas service fails; or 2) for the emergency pumping of water for either fire protection or flood relief. An emergency standby engine may not be operated to supplement a primary power source when the load capacity or rating of the primary power source has been either reached or exceeded.

E. **New Diesel-Fueled Engine:** A new diesel-fueled engine is either:

1) A new diesel-fueled engine installed at a new or existing source. An exact replacement is considered the addition of a new diesel-fueled engine;
2) The relocation of any diesel-fueled engine from an off-site location; or
3) A reconstructed diesel-fueled engine, where a reconstructed diesel engine is one where the cost of reconstruction is greater than or equal to 50% of the purchase price of a new similarly sized engine (basic equipment only).

V. The Basic Approach

1) *Since particulate matter from diesel-fueled engines has been identified as a non-threshold carcinogen, we are suggesting in this guidance that any new stationary diesel-fueled engine meet the most stringent particulate matter (PM) certification level that is currently being met by a similar engine.*

In determining the most stringent particulate matter certification level that is currently being met, we looked at both on-road and non-road certification data. Comparison of on-road and non-road standards is not straightforward, since non-road test procedures are done in accordance with ISO 8178 steady-state test procedures and on-road diesel-fueled engines are tested in accordance with FTP transient test cycles. The limited engine test results we have seen show that an engine tested on both transient and steady-state test cycles, will generally show a lower PM emission rate during the steady-state test cycles. Therefore, we are assuming that an engine that can meet an on-road certification level (transient test) will meet a similar off-road certification level (steady-state test).

2) *We are suggesting in this guidance that add-on control equipment be required on most diesel-fueled engines, in consideration of costs and technical feasibility.*

In general, engines that are operated for extended periods of time emit the most PM and pose the greatest risk. We have conducted air dispersion modeling analysis varying the horsepower and annual hours of operation for representative stationary diesel-fueled engines operating in California. We have analyzed the results of our modeling efforts and we recommend that add-on controls be required on those engines that are greater than 50 horsepower with annual hours of operation in excess of 50.

Add-on control equipment options that are currently being used in on-road diesel engine applications are expected to be utilized in non-road stationary diesel-fueled engine applications. These include diesel oxidation catalysts (DOC) and diesel particulate filters (DPF). Some unique aspects of the operating environment or performance requirements of a non-road engine may govern the application of some control equipment options. For example, particulate traps generally require engine exhaust to meet a certain temperature for a portion of the duty cycle to facilitate filter regeneration. A non-road diesel-fueled engine that operates at a low load and cyclical speeds may not generate an exhaust temperature that is sufficient to regenerate the filter, even when the filter is catalyzed. For these cases, an electrically powered heater for filter regeneration may be the preferred option. We believe in most situations, add-on controls are both technically and economically feasible for new engine applications.

3) *We are suggesting in this guidance that a site-specific HRA be conducted on diesel-fueled engines that are greater than 50 horsepower and operate over 200 hours a year to ensure the lowest achievable risk level will be achieved, in consideration of cost and technical feasibility of control.*

Our air dispersion modeling results indicate that diesel-fueled engines operated over 200 hours per year may result in nearby receptors being exposed to elevated levels of diesel particulates. HRA results, as well as other site-specific findings such as the location of sensitive receptors, should be considered when permitting these engines. We suggest that the public review and comment on the proposed permit action prior to the district's final decision.

VI. Permitting Requirements

This section identifies and discusses the suggested minimum technology requirements for permitting new or relocated diesel-fueled engines operating at stationary sources. The suggested minimum technology requirements are based on current engine, add-on control, and fuel technologies. These requirements will need to be reevaluated if engine certification standards or diesel fuel specifications change significantly. Table 1 summarizes these requirements.

Table 1: Permitting Requirements for New or Relocated Diesel-Fueled Engines

Engine Category	Annual Hours of Operation	Tier	Minimum Technology Requirements			Additional Requirements	
			New Engine PM Emission Certification Levels[1] (g/bhp-hr)	Fuel Technology Requirements	Add-On Control	HRA Requirement	SF Report
Engines $\leq$ 50 hp	All	1	0.2-0.4	CARB Diesel[2] or equivalent	No	No	No
Engines > 50 hp	$\leq$ 50 hours	1	0.1	CARB Diesel or equivalent	No	No	No
	> 50 hours and $\leq$ 100 hours	1	0.1	CARB Diesel or equivalent	DOC or equivalent	No	No
	> 100 hours and $\leq$ 200 hours	1	0.1	CARB Diesel or equivalent	DPF or equivalent	No	No
	> 200 hours	2	0.1	CARB Diesel or equivalent	DPF or equivalent	Yes	If HRA shows risk > 10/million

1 All steady-state tests.
2 We encourage the use of CARB diesel formulations with the lowest available sulfur content.
HRA - Health Risk Assessment SF - Specific Findings DOC - Diesel Oxidation Catalyst
DPF - Diesel Particulate Filter

The suggested minimum technology requirements are established for two categories of stationary diesel-fueled engines: engines with horsepower ratings equal to or less than 50 and engines with horsepower ratings greater than 50. A review of air dispersion modeling results have indicated that engine horsepower, or size, does not have as significant an impact on the maximum risk from emissions of PM as the PM emission certification level and the number of hours the engine is operated. (Appendix 2 summarizes the potential risks associated with the air dispersion modeling results that were reviewed when defining the minimum technology requirements.) Therefore, we believe a minimum technology requirement, as defined by the PM emission certification level, is appropriate for all sizes of engines that fall into these two categories.

For all stationary diesel-fueled engines, we suggest requiring the use of CARB diesel or an equivalent fuel. California's diesel-fuel regulation contains two principal requirements: fuel sulfur content is capped at 0.5 % by weight and aromatic content is capped at 10% by volume. Both requirements result in lower PM emissions. A low sulfur content also maximizes the effectiveness of catalytic add-on controls. For this reason, we suggest that districts consider requiring the use of CARB diesel formulations with sulfur contents below the 0.5% cap where available. To date, CARB has certified alternative California diesel fuel formulations with sulfur content limits as low as 33 parts per million (ppm) (0.0033% by weight). In-field compliance testing has shown that some CARB diesel-fuel samples have sulfur contents below 10 ppm by weight. With this in mind, we believe districts should consider requiring stationary diesel-fueled engines to operate only on CARB diesel fuel with sulfur contents not to exceed 15 ppm (0.0015% by weight) where available.

The following paragraphs discuss in more detail the two categories of diesel-fueled engines and the basis for the new engine particulate matter certification levels and add-on control requirements. A detailed discussion of the suggested process for making permitting decisions is contained in Section VII, Approval Process.

A. Engines $\leq$ 50 hp

1. Description

A majority of the engines $\leq$ 50 horsepower (small engines) used throughout the state are used in mobile and portable applications, (i.e., skid-steer loaders, commercial turf mowers, portable generator sets, and portable compressors). Currently, small stationary engines are exempted from most district permitting requirements, so we do not have an accurate estimate of how many are currently operating in the state. From the limited information we have, we estimate small stationary diesel-fueled engines comprise less than 10% of the small engines operated in the state (ARB, June 14, 1999).

2. New Engine Certification Levels

Assuming that stationary diesel-fueled engines 50 horsepower or less make up a very small percentage of the stationary diesel-fueled engine inventory, the impact of controlling the PM emissions from small engines may not be great. However, given the classification of PM as a nonthreshold carcinogen, we believe minimum technology requirements should be required for all new source of diesel PM, including small engines. We suggest the minimum technology requirements for new stationary small engines should be equal to: 1) the most stringent PM certification level currently being met by similar engines, and 2) the use of CARB diesel. We have data that shows that some engines 50 hp or less are currently meeting 0.2 to 0.4 g/bhp-hr (steady-state) certification levels (U.S. EPA, August 8, 1997).

3. Add-on Controls

No add-on controls are suggested for small engines.

B. Engines > 50 hp

1. Description

This category includes all stationary diesel-fueled engines with horsepower ratings greater than 50 hp. There is a multitude of uses for engines in this category. Typically, stationary diesel-fueled engines are used in the following types of applications: cranes, pumps, welding, woodchippers, power generation, compressors, and rockcrushing. This category also addresses emergency standby engines. Emergency standby engines are used to either provide emergency electrical power or the emergency pumping of water for flood relief or fire protection. Several types of facilities are required to have standby engines to provide emergency power systems. These include hospitals, airports, correctional facilities, and city sewage and water plants. Many large office buildings and apartment complexes also have emergency standby engines. Emergency standby engines can range from 50 hp to over 1000 hp.

Currently, most districts exempt emergency standby engines from new source permitting requirements. We suggest emergency standby engines be included in district permitting rules since a significant amount of PM emissions can be emitted during maintenance operations. Many facilities with emergency standby engines are required to conduct maintenance runs to ensure the operational readiness of the engine. Typical maintenance runs are conducted at minimal load and can last from five minutes to two hours. The frequency of maintenance runs can vary from once a year, to once every seven days. ARB estimates that emergency standby engines comprise approximately 90% of the stationary diesel-fueled engines located throughout the state and emit over 130 tons of diesel PM a year. (ARB, December 23, 1999)

2. New Engine Certification Level

We suggest that all new permits for stationary diesel-fueled engines rated at 50 horsepower or greater require the applicant to use engines certified to meet a PM emission standard of 0.1 g/bhp-hr over a steady-state test cycle (ISO 8178). We base this suggestion on existing PM emission standards and engine certification data for model year 1999 and 2000 engines.

Table 2 lists the existing California Diesel Engine Certification Standards for both on-road and non-road diesel-fueled vehicles and engines.

As shown in Table 2, the most stringent non-road engine PM certification

Table 2: California Diesel Engine Certification Standards
(1991 to 2006 & Later)

Category	Engine Rating	PM Emission Standard															
	hp	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006 & later
Passenger cars and light-duty trucks*	120-200	0.08 g/mile		0.08 g/mile (TLEV &LEV)												0.04 g/mile (TLEV)	
(continued)	120-200	NA		0.04 g/mile (ULEV)												0.01 g/mile (LEV,ULEV,SULEV)	
Medium-duty*	200-300	NA	0.1 g/bhp-hr (LEV & ULEV)														
(continued)	200-300	NA				0.1 g/bhp-hr (Tier I)											
(continued)	200-300	NA					0.05 g/bhp-hr (SULEV)										
Heavy-duty*	250-500	0.25 g/bhp-hr			0.1 g/bhp-hr												
Non-road	0-11	NA					0.9 g/bhp-hr				0.75 g/bhp-hr					0.6 g/bhp-hr	
(continued)	11-25	NA					0.9 g/bhp-hr				0.6 g/bhp-hr						
(continued)	25-50	NA								0.6 g/bhp-hr					0.45 g/bhp-hr		
(continued)	50-100	NA													0.3 g/bhp-hr		
(continued)	100-175	NA												0.22 g/bhp-hr			
(continued)	175-300	NA					0.4 g/bhp-hr							0.15 g/bhp-hr			
(continued)	300-600	NA					0.4 g/bhp-hr					0.15 g/bhp-hr					
(continued)	600-750	NA					0.4 g/bhp-hr						0.15 g/bhp-hr				
(continued)	>750	NA									0.4 g/bhp-hr						0.15 g/bhp-hr
Urban Bus Engines*	250-300	0.1 g/bhp-hr			0.07 g/bhp-hr		0.05 g/bhp-hr										

*Transient Test

standards for diesel-fueled engines greater than 50 hp for the year 2000 range from 0.60 to 0.15 g/bhp-hr, depending on the engine's horsepower rating. However, for engines in the 200-500 horsepower range, the year 2000 on-road PM emission standards are significantly more stringent than the comparable off-road standards (0.1 g/bhp-hr as compared to 0.4 g/bhp-hr). As mentioned previously, the on-road standards are Federal Test Procedure (FTP) transient test certification levels while the off-road standards are ISO 8178 steady state certification levels. The limited engine test information we have seen indicates that an engine that is certified to 0.1 g/bhp-hr via a transient test would certify to less than 0.1 g/bhp-hr via a steady-state test. This supports our suggestion that a 0.1 g/bhp-hr (steady-state) standard certification level is achievable by engines within the 200-500 horsepower range.

Similarly, we believe a standard of 0.1 g/bhp-hr (steady-state) is appropriate for stationary diesel-fueled engines within the 120 – 200 horsepower range based on current on-road standards. On-road diesel-fueled vehicles equipped with engines in the 120-200 hp range must comply with 0.08 and 0.04 gram/mile certification standards. These vehicles are tested on a vehicle chasis dynanometer. The 0.08 and 0.04 gram/mile vehicle standards are roughly equivalent to the 0.1 and 0.05 g/bhp-hr transient engine test standards, respectively.

Further, for diesel-fueled engines between 50 and 800 hp, we have U.S. EPA Non-road Engine Certification Data that shows some model year 1999 and 2000 diesel-fueled engines are currently meeting 0.04 to 0.13 g/bhp-hr (steady-state) certification levels.

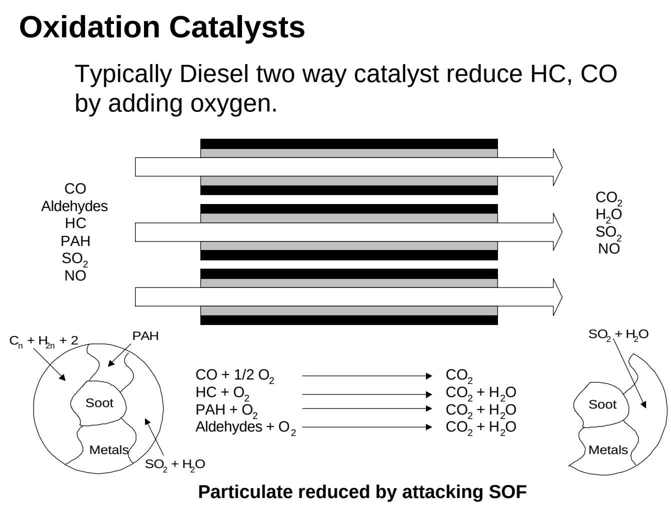
3. Add-on Control

We are suggesting that stationary diesel engines that operate between 50 and 100 hours per year be required to install a diesel oxidation catalyst (DOC) or equivalent control technology. For engines that operate more than 100 hours per year, we suggest that a DPF or equivalent control technology be required. DOCs and DPFs are two exhaust treatment devices that have shown through testing and in-use applications to be effective at reducing PM emissions. In general, a properly sized and installed DOC can reduce PM mass emissions about 20%, while a DPF can reduce PM emissions about 70%.

4. DOCs and DPFs

Diesel Oxidation Catalysts (DOCs)

In general, DOCs reduce PM, carbon monoxide, and hydrocarbon emissions through catalytic oxidation (See illustration below). Most catalysts reduce only the soluble organic fraction (SOF), i.e., unburned fuels, oils, and sulfates. The catalytic conversion process requires a heat source, so choosing the location of the catalyst within the exhaust system is important. At relatively low exhaust stream temperatures, which generally occur at low revolution and or low load operations, the closer the DOC is located to the exhaust manifold, the greater the SOF removal efficiency will be.



In most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures and with the presence of sulfur in the fuel. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with very low sulfur content.

Some manufacturers integrate hydrocarbon traps (zeolites) and sulfate suppressants into the oxidation catalysts. Hydrocarbon traps enhance hydrocarbon reduction efficiency at lower temperatures and sulfate suppressants minimize the generation of sulfates at higher exhaust temperatures.

PM reduction varies with exhaust temperature and can be as high as 15% by mass at 150° C to more than 50% at 350° C. Control efficiency estimates are dependent on the diesel-fueled engine's baseline PM emission level, sulfur content of the fuel, and the test method used to estimate emissions. Steady-state emission tests of older diesel-fueled engines equipped with DOCs have shown overall reduction in PM of up to 21%. Transient tests of urban buses equipped with DOCs have shown overall reduction of PM of up to 30%. (See Appendix 1). The Manufacturers of Emission Controls Association (MECA) instituted a test program (MECA study) at Southwest Research Institute to evaluate the performance of a variety of commercially available exhaust emission control technologies on a current design heavy-duty diesel engine. The results of the MECA study were published in a report titled, Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels, Final Report, June 1999. The results indicate that PM reduction of a properly sized catalyst, that is one whose displacement is at least equal to the displacement of the engine, can reduce emissions 30% or more while using a fuel with a sulfur content of 368 ppm.

In general, the initial cost of a DOC can range from 2% to 6% of the cost of a new generator set.

DOCs are discussed in more detail in Appendix 1.

Diesel Particulate Filter (DPF)

DPFs reduce PM emissions by trapping the particles in a flow filter substrate where it is oxidized, or burned-off, once the filter reaches a certain temperature. This burn-off process is referred to as filter regeneration. Unlike DOCs, DPFs remove the solid, dry carbon (soot) from the exhaust stream. DPFs also reduce CO and hydrocarbon emissions, if catalyzed.

For most applications, passive regeneration of the filter at exhaust temperatures is difficult to achieve during normal operating conditions.

For this reason, most DPFs incorporate a catalyst that effectively lowers the soot burn-off temperature. Most DPF manufacturers apply a catalytic coating directly to the filter element, others manufacture systems that incorporate a fuel-borne catalyst or electrically powered heating units used in conjunction with an uncatalyzed filter. Catalyzed DPFs are discussed in more detail in Appendix 1. The catalyst not only promotes the burn-off of soot, but, as with DOCs, also reduce the SOF, HC, and CO.

As with DOCs, the formation of sulfate particles increases at higher temperatures and with the presence of sulfur in the fuel. This effect can be minimized by using diesel fuel with very low sulfur content.

Steady-state emission testings of older diesel-fueled engines equipped with DPFs have shown overall reduction in PM of up to 85%. Transient tests of a hybrid diesel-electric engine and of a diesel-fueled engine used in a wheel loader application have shown reductions in PM of 92% and 97%, respectively. The results of the MECA study indicate that a DPF can reduce emissions at least 78% while using a fuel with a sulfur content of 368 ppm. Recently, two large diesel-fueled engines, over 1000 hp, and two DPFs were installed at a facility in Northern California. The manufacturers of the DPFs claim the PM reductions of 65% can be expected if the engines are fueled with California diesel. The ARB will source test these two engines.

In general, the initial cost of a DPF can range from 14% to 18% of the cost of a new generator set.

VII. Approval Process

A. Overview

This section identifies the suggested approach for permitting new stationary diesel-fueled engines. As discussed in the previous section, we are suggesting grouping all stationary diesel-fueled engines into two broad categories: engines with horsepower ratings 50 hp or less and engines with horsepower ratings greater than 50 horsepower. The source would identify the appropriate category for the engine they plan to install and the maximum number of hours a year the engine will operate. Minimum technology requirements would be required to be met before a permit is approvable[3]. These requirements are summarized in Table 1. For engines that will operate over 200 hours a year, a site-specific HRA must be completed prior to the district approving the permit. A Specific Findings (SF) report would also be required if the HRA shows the cancer risk from the engine is greater than 10 chances per million. Engines whose permits would be approvable without a site-specific HRA being

3 Assuming source meets all other district requirements and all applicable state or federal requirements.

prepared are referred to in this report as Tier 1 engines. Engines for which the district requires an HRA be prepared are referred to as Tier 2 engines. The following text and Figure 1 describe in more detail the suggested approach for permitting new stationary diesel-fueled engines.

Figure 1. Conceptual Decision Flow Chart for Permitting New Stationary Diesel-Fueled Engines

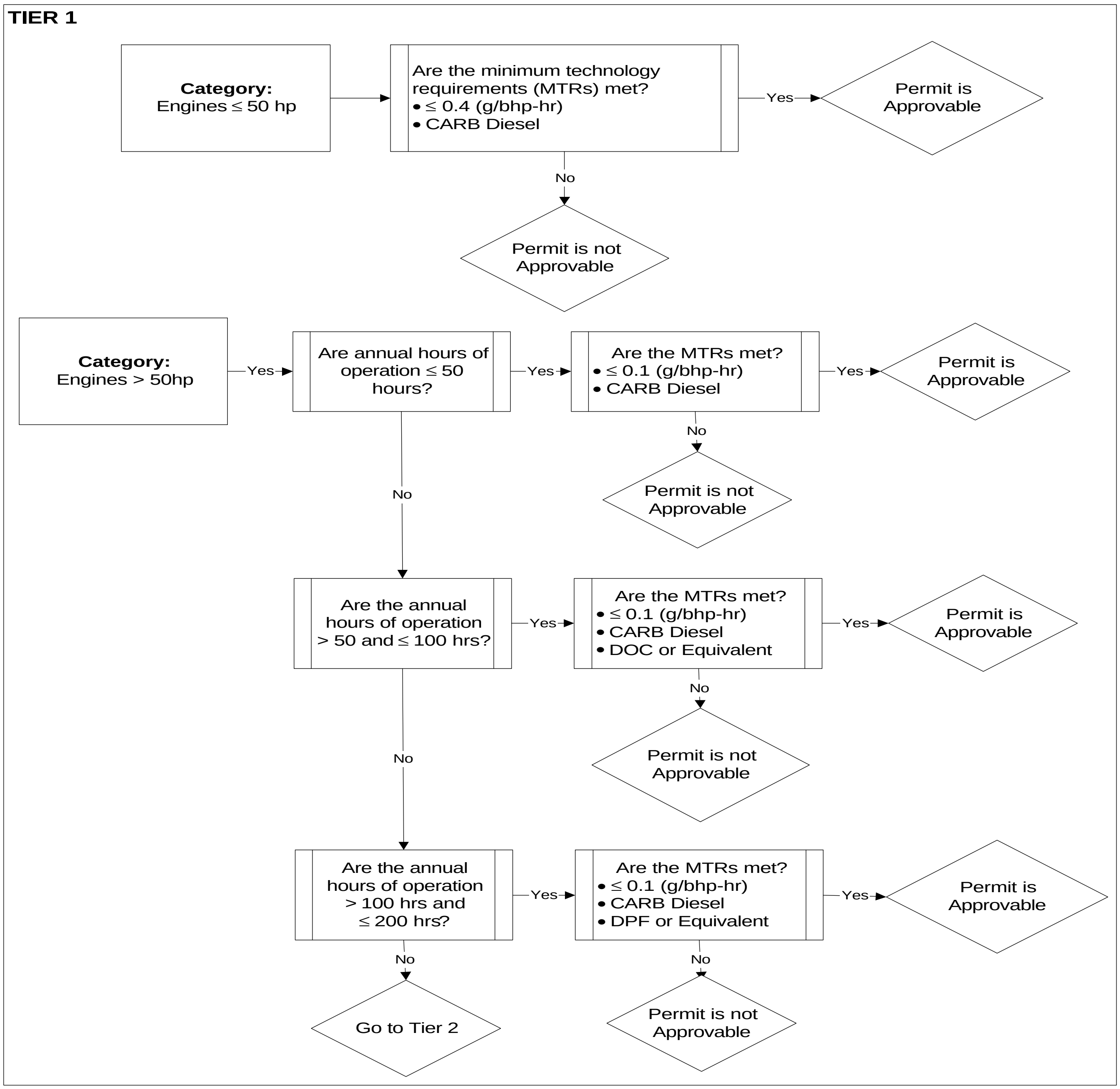
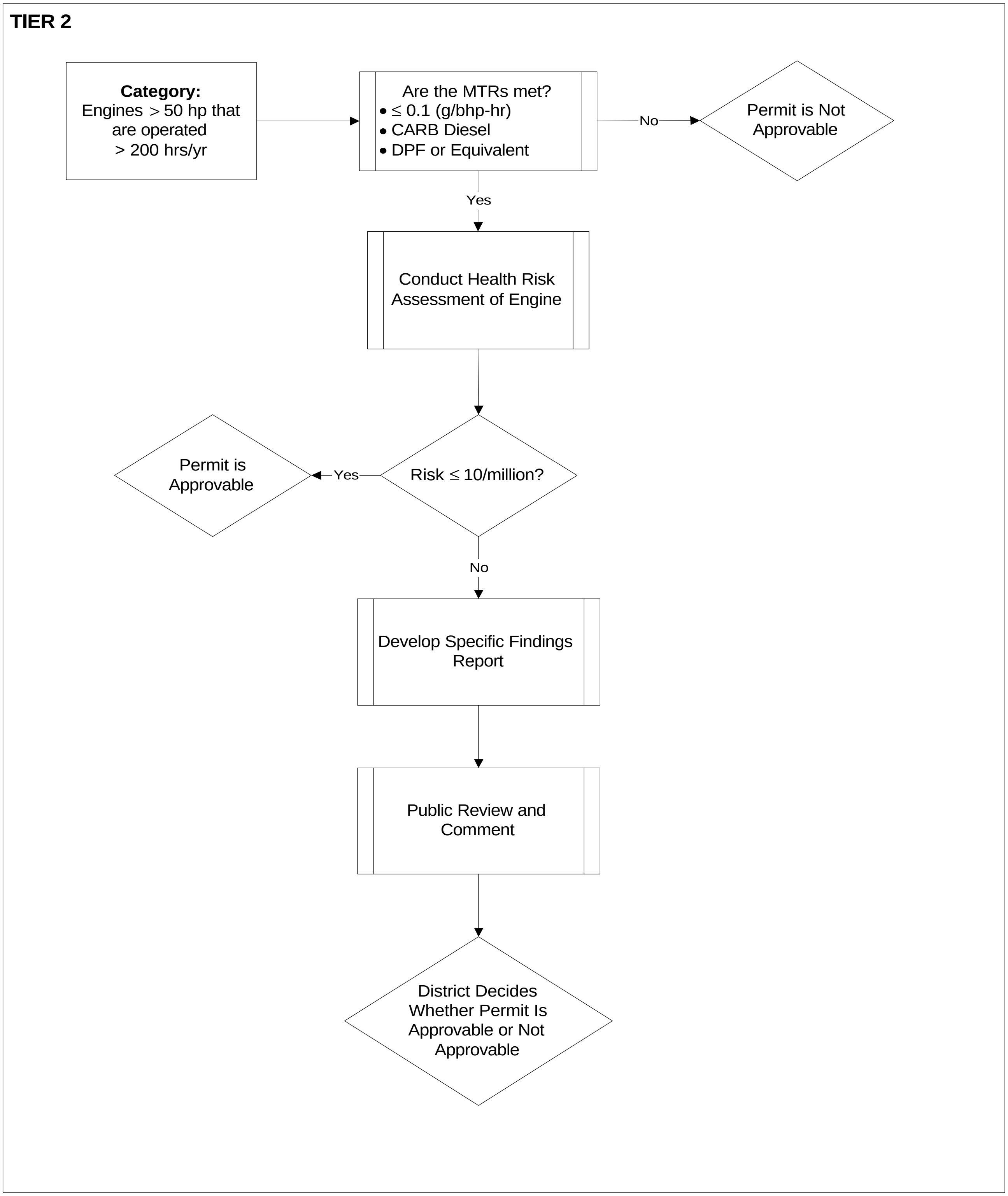


Figure 1 (continued)



B. Tiered Approach

All diesel-fueled engines required to obtain a district operating permit would fall into one of two groups of categories, Tier 1 or Tier 2.

We suggest that engines from Tier 1 categories would be approvable if they meet or exceed the appropriate minimum technology requirement. We believe that most permitted stationary diesel-fueled engines will be Tier 1 engines. Tier 1 engines include all engines with horsepower ratings less than or equal to 50, and all engines with horsepower ratings greater than 50 that are operated 200 hours a year or less (see Table 1). For emergency standby engines, the annual hours of operation are defined as the scheduled hours the engine is operated to insure its readiness in times of emergency.

Tier 2 engine categories represent those stationary diesel-fueled engines operated more than 200 hours per year. (See Table 1.) Engines from the Tier 2 category would be required to meet or exceed the appropriate minimum technology requirement for the engine and perform a site-specific screening HRA. Based on the screening HRA, the district would determine if a more detailed analysis or if a Specific Findings Report were necessary. Criteria for determining if a more detailed analysis or if a Specific Findings Report is necessary, could include factors such as:

- availability of electricity or natural gas (note: not applicable to emergency standby engines);
- proximity of sensitive receptor location, i.e., school or daycare center;
- existing risk posed by facility;
- multiple engines being installed at the same location;
- screening HRA that shows the potential cancer risk from PM emissions from the engine is significant (e.g., PM inhalation cancer risk is greater than 10 in a million); or
- availability of cleaner diesel fuel.

The screening HRA need only evaluate the inhalation cancer risk posed by the emissions of PM from stationary diesel-fueled engines. In identifying PM emissions from diesel-fueled engines as a toxic air contaminant, the SRP recommended a reasonable unit cancer risk (300 chances per million per $\mu g/m^3$) when determining the cancer risk from inhalation, and a reasonable exposure level (REL) of 5 $\mu g/m^3$ when evaluating chronic noncancer risk. An acute noncancer risk REL was not recommended at this time, however acute RELs for several of the TACs found in the diesel exhaust have been approved by the SRP. Therefore, cancer risk from inhalation of PM and noncancer risk, as expressed as a hazard index value, from PM (chronic) and from other TACs which are found in diesel exhaust (acute), can be estimated. However, our analysis shows that the cancer risk from inhalation is the critical path when comparing cancer and noncancer risk. In other words, a cancer risk of 10/million from the inhalation of PM will result from PM concentrations that are much less than the

PM or TAC concentrations that would result in chronic or acute noncancer hazard index values of 1 or greater.

For engines requiring a more detailed analysis and Specific Findings Report, we are suggesting public review and comment on the proposed permitting action. The type of information needed for a more detailed analysis is presented in the following section.

C. Detailed Analysis - Specific Findings Report

This section only applies to Tier 2 categories of engines. We suggest that the district review site-specific information when making a permitting decision for a Tier 2 engine. Listed below are examples of the type of information we believe should be reviewed by the district. The district's analyses would be discussed and summarized in a Specific Findings Report, which would be made available to the public for review and comment.

The following information may be included in the Specific Findings Report:

- An evaluation of the technical and economic feasibility using cleaner diesel fuel or a non-diesel-fueled (i.e., electric or natural gas) engine.

- A site-specific HRA of the stationary diesel-fueled engine(s). The OEHHA is currently developing risk assessment guidelines that when complete, should be used when conducting site-specific risk assessments. Until the OEHHA completes its work on the guidelines, we believe that risk assessments should be done in accordance with the most current version of the *CAPCOA Air Toxics "Hot Spots" Program Risk Assessment Guidelines*. Section VII of this guidance, Diesel-Specific Adjustment to the Existing Risk Assessment Methodology, identifies diesel-specific adjustments that can be made in conducting risk assessments of stationary diesel-fueled engines.

- An evaluation of site-specific design considerations that would be employed to minimize the impact of particulate matter emissions from stationary diesel-fueled engine(s) on near source receptors. Table 3 presents a list of possible options.

Table 3: Source Design Options

Optimizing diesel engine stack height	Maximizing buffer zones via diesel engine location
Operating at times of day that have the least impact	Locating engine to take advantage of meteorology
Non-full load testing	Inspection/maintenance program

- An evaluation of the technical and economic feasibility of emission reduction options that would provide particulate emission reductions beyond the minimum technology requirements.
- An evaluation of the technical and economic feasibility of emission reduction options that are likely to be available in the next three years which would provide particulate emission reductions beyond the minimum technology requirement.
- An evaluation of the risk contributed by other proposed or existing diesel-fueled engines at the source.
- An evaluation of the risk contributed by other non-diesel-fueled equipment at the source.
- A facility-wide risk assessment.
- A discussion of the uncertainty associated with the emissions, exposure, or risk estimates.
- A discussion of the benefits associated with the proposed project.
- A discussion of any existing federal, state, or local mandates that require the proposed project.
- A discussion of facility risk relative to ambient levels.
- A discussion of the impacts of the proposed project on media other than air.

The date when public comments on the Specific Findings Report are due to the district and the date when the final permitting decision is to be made should be included in the Specific Findings Report. If the district is planning to conduct a public meeting to discuss the proposed permitting action and Specific Findings Report, information on when and where the meeting or meetings will be held should be included in the Specific Findings Report.

D. Evaluation of Alternatives to Add-On Control Requirements

The suggested minimum technology requirements for diesel-fueled engines require a DOC, DPF, or equivalent add-on control technology, be installed on diesel-fueled engines that meet certain horsepower and annual hours of operation criteria. We suggest for alternatives to DOCs, a PM emission reduction of 20% or greater be demonstrated. We believe a 20% reduction is achievable based on the average PM reduction of the DOC emission tests summarized in Appendix 1 (23% reduction) and the MECA study (26% reduction). Similarly, for DPFs, we suggest a PM emission reduction of 70% or greater be demonstrated. We believe a 70% reduction is achievable based on the average PM reduction of the catalyzed DPF emission tests summarized in Appendix 1 (91% reduction); the PM reduction of an uncatalyzed DPF as reported in SAE Technical Paper # 1999-01-0110 (79% reduction); and the PM reductions reported in the MECA study, which tested both catalyzed and uncatalyzed DPFs used in conjunction with fuel-borne catalysts (77% reduction).

In order to insure that the PM emission reductions associated with the alternative add-on control technology meet or exceed the 20% or 70% emission reduction criteria, we suggest that the diesel-fueled engine and alternative control be source tested. Appendix 3 is a draft source test protocol that is currently being developed by the ARB to test the effectiveness of two DPFs at a specified source. The section of the protocol that evaluates the effectiveness of add-on control equipment is applicable here. The source test requires the diesel-fueled engine to be run at speeds and loads that would reflect the engine's operating scenario. PM emissions samples would be collected from the engine's exhaust stream before and after the add-on control technology. The percent reduction of PM emissions resulting from the alternative add-on control equipment would be calculated using the sampled PM emissions. This calculated PM percent reduction would be compared to the appropriate 20% or 70% PM emission reduction criteria to determine if the alternative is approvable.

Another important consideration when choosing an alternative control technology is the control technology's effect on NOx emissions. Alternative control technologies should not be approved if they result in a NOx emission rate that exceeds the engine's certification level.

VIII. Diesel-Specific Adjustment to the Existing Risk Assessment Methodology

A. Use of Exposure Adjustment Factors from Draft OEHHA Risk Assessment Guidelines

This guidance recommends risk assessments be conducted in accordance with the *CAPCOA , Air Toxics "Hot Spots" program, Revised 1992 Risk Assessment Guidelines*, October 1993. However, the OEHHA is currently revising these guidelines and is expected to complete them by July 2000. The revised guidelines should be used when they are finalized.

During the development of this guidance, a number of issues were raised regarding the appropriateness of using some of the risk characterization exposure assessment parameters found in the draft OEHHA Risk management Guidelines prior to their approval. Table 4 identifies the exposure assessment issue, ARB's position on the issue, and ARB's recommendation on how the issue should be addressed.

Table 4: Risk Characterization Exposure Assessment Issues for Consideration in OEHHA's New Risk Assessment Guidelines

Issue	ARB Position	Recommendation
Use of Stochastic Analysis Techniques Found in OEHHA's Draft Exposure Assessment Document	Completion of public and peer review process is needed before OEHHA can recommend using probabilistic approaches. Districts may consider stochastic analyses provided as supplemental information to the standard risk assessment information.	Permit applicants may provide stochastic analysis as a supplement to the analysis recommended by the existing risk assessment guidelines. Information and comments concerning stochastic analysis should be provided to OEHHA.
Use of Exposure Assessment Parameters Found in OEHHA's Draft Exposure Assessment Document: **Breathing Rate**	Breathing Rate: Completion of public and peer review process is needed before OEHHA can recommend using probabilistic approaches addressed in the draft revised risk assessment guidelines. Districts may consider alternative breathing rate information as supplemental information to the standard risk assessment information	Permit applicants may submit alternative information based on breathing rate as supplemental information to the risk assessment.
Use of Exposure Assessment Parameters Found in OEHHA's Draft Exposure Assessment Document: **Exposure Duration—Years per Lifetime** **Project Duration More Than Two Years.**	Completion of public and peer review process is needed before OEHHA can recommend using a lifetime exposure duration different than 70 years. Districts may consider alternative lifetime exposure duration information as supplemental information to the standard risk assessment.	Permit applicants may submit information based on less than 70 years exposure as supplemental information to the risk assessment.
Exposure Assessment Issue **Exposure Duration—Years per Lifetime Project Duration Less Than Two Years.**	Use 9/70ths of risk calculated based on 70 years of exposure. See Table 3 Limited Duration Project.	
Exposure Assessment Issue **Exposure Duration—Hours per Day**	The draft risk assessment guidelines do not propose using alternative exposure duration for hours per day exposure. Districts may consider alternative daily exposure duration information as supplemental information to the standard risk assessment information.	Permit applicants may submit information based on a less than 24 hour per day time-at-location as supplemental information to the risk assessment.

B. Use of Site-Specific Exposure Adjustments

In addition to the risk characterization exposure assessment issues addressed in Table 4, there were a number of site-specific risk assessment issues identified during the development of this guidance. Table 5 identifies the site-specific exposure assessment issue, ARB's position on the issue, and ARB's recommendation on how the issue should be addressed.

Table 5: Site-Specific Exposure Assessment Issues to be Addressed by the ARB

Issue	ARB Position	Recommendation
Application of an Indoor/Outdoor Correction Factor	Generic use of an indoor/outdoor correction is not appropriate. Methodology is needed to determine appropriate correction factor on a site-specific or situation-specific basis.	Use recommended correction factors identified in Section VIII, C.
Particle Size Correction	Exposure and risk calculations for permitting decisions should be based on the PM_{10} concentration.	Exposure and risk calculations for permitting decisions should be based on the PM_{10} concentration.
Application of a Wet Deposition Correction Factor	It may be appropriate to include a wet deposition in site-specific risk assessment. Rain will affect dispersion by removing PM from the air. It could also impact the non-inhalation pathway by increasing near-source deposition.	Currently, there is no ARB approved methodology for estimating the reduction in PM concentration due to the scavenging of PM via precipitation. However, permit applicants may submit supplemental information to the risk assessment that includes the application of a wet deposition correction factor.
Use of Area-Specific Meteorology	It is appropriate to use area-specific meteorology in risk assessment where available, provided it is appropriate for use.	ARB has identified 30 meteorological data sets that are acceptable for use. We would encourage/support a research project to identify additional data sets and/or an analysis to extend the use of existing met data without measurements of key parameters at 30 meter elevations. We strongly recommend district's contact ARB staff to discuss the appropriateness of using meteorological data sets that are not among the 30 sets identified.
Use of Stack-Configuration Information	It is appropriate to adjust for stack configuration in site-specific risk assessment. However, new sources should require vertical stacks without fixed rain caps.	ARB will examine existing methodology for modeling non-vertical stacks and stacks with rain caps to determine if it is appropriate for use. (Still working on issue.)
Accounting for Different Dispersion Parameters Based on the Time-of-Day of the Emissions	It may be appropriate to take into consideration the time-of-day of periodic emissions in site-specific risk assessment.	Permit applicants can use modeling based on time of day of emissions, but permit needs to have an enforceable time-of-day limit.

Table 5: Site-Specific Exposure Assessment Issues to be Addressed by the ARB (Con't)		
Issue	**ARB Position**	**Recommendation**
Application of a Pre-1993 Diesel-Fuel Correction Factor	It is appropriate to use a correction for emission factors developed prior to the introduction of CARB diesel (1993).	ARB recommends using the on-road fuel correction factor. For 94+ engines the correction factor is 0.8972.
Use of Other Dispersion Models	Models other than those listed in the CAPCOA guidelines that reflect state-of-the-science air dispersion modeling techniques should be allowed to be used.	ARB will evaluate and authorize the use of new models as they become generally available. If there are specific models not currently authorized for use by ARB, a request for evaluation/authorization should be provided.
Use of Existing Models within 100 meters of Source	Continue to use existing approved models for assessing the exposure/risk within 50 meters of an emission point. Acknowledge model performance more uncertain within 50 meters.	ARB is preparing a research proposal for a study to evaluate the applicability of existing models for air concentrations within 50 meters of an emission point. We are seeking additional funding for model validation work. ARB's position is that use of modeling results down to 20 meters is appropriate for most models.
Additional Worker Exposure Correction Factors	Provide additional guidance for worker exposure correction factor for teachers.	Develop methodology for inclusion in guidance. Teachers would receive 46/70 correction plus additional site-specific corrections based on scheduled hours of engine operation.
Evaluating future changes in emissions/risk due to current regulatory requirements	For long-term projects, it is appropriate to take into consideration future reductions that are required by regulation or permit.	Develop methodology for a time-weighted risk analysis. This is being evaluated as part of the "Risk Characterization Scenarios Analysis".
Limited Duration Projects	For sources that will only operate for a short duration (no more than two years), calculate the risk based on the source operating 70 years, but use 9/70ths of the calculated risk as the risk contribution from the source.	In consultation with OEHHA, ARB recommends a 9/70ths correction be applied to the 70 year risk calculations for limited duration projects.

C. Indoor/Outdoor Correction Factor

Table 6 identifies the suggested indoor correction factors to be used when estimating site-specific risk for the types of buildings and environments listed. These factors account for the expected differences in indoor and outdoor concentrations. These correction factors do not account for time spent in a particular building or environment. The indoor correction factors should only be used in modeling situations where the modeled output is exposure based on a duration of 24 hours a day for 70 years.

The following example shows how the information in Table 3 should be used.

Example: A diesel generator operates 8 hours/day, 5 days a week. ISCST3 modeling results show PM concentration levels at a nearby large office building to be 3 $\mu g/m^3$. This exposure level represents the average annual concentration a person would be exposed to in an outdoor environment. If the point of maximum impact was an office building with a central heating and air conditioning system, the exposure to someone indoors at the office building would be calculated as follows:

(Outdoor PM concentration)	(Indoor/outdoor correction)		(Indoor PM concentration)
(3 $\mu g/m^3$)	(0.7)	=	2.1 $\mu g/m^3$

Table 3: Suggested Correction Factors for Particle Levels Inside Buildings		
Structure Type	Recommended Correction Factor (indoor/outdoor)	
Residences		1
Offices	Large, or with filtration	0.7
Industrial Plant		1
Schools	Large, or with filtration	0.8
	Small, or no filtration	1
Travel In-Vehicle		1
Stores and Public Buildings (Retail)	Large, or with filtration	0.9
	Small, or no filtration	1
Restaurants and Lounges	Large, or with filtration	0.9
	Small, or no filtration	1
Other Indoors	Large, or with filtration	0.7

Source: ARB

IX. Discussion of the Uncertainty Associated with Risk Assessment

(from the *Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Appendix III, Part B, Health Risk Assessment for Diesel Exhaust*, pages 1-13 through 1-14)

Results based on the human data and those based on the animal data are both subject to considerable uncertainty. The strengths and weaknesses of calculating population risks using the human studies (Garshick et al., 1987a; Garshick et al., 1988) and the animal bioassay (Mauderly et al. 1987a; Brightwell et al., 1989; Heinrich et al., 1995; Ishinishi et al., 1986a; Nikula et al., 1995) are summarized in Table 7-6.

The principal uncertainties in using the rat data are their application to humans in terms of response, the choice of dose-response model to extrapolate the risk to environmental concentrations, and the range of dose extrapolation involved.

The principal uncertainties in using the human data are the representativeness of railroad workers for the general population, the choice of the analytical model, and the lack of knowledge of the exposure history of the railroad workers including possible exposure to unknown confounders. The historical reconstruction here is based upon the Woskie et al. (1988b) exposure data for railway workers and the rate of dieselization for U.S. railroads. Using a range of reduced emission assumptions, alternative exposure patterns are considered. This reconstruction takes into account to some degree the likely higher exposure levels in the past. If actual exposures were higher than assumed here, then our estimates of the risk would be lower. If exposures were lower, then the estimated risks would be higher. The range of extrapolation from these estimated occupational exposure levels to the California population-weighted annual average exposure of 1.54 µg diesel exhaust particulate/m^3 *is not large.*

Table 7-6 Human and Animal Information for Quantitative Estimates of Risk.

Information/Advantage[a]	Animal[b]	Human[c]
Accuracy of exposure estimate in study A++	Numerically precise for rats exposed to automobile exhaust	Uncertain for the railroad workers
Ratio of study exposure to human environmental exposure H++	300	7
Similarity of study exposure to present day exhaust A+	Some uncertainty	Some uncertainty. Uncertain quantitative control for smoking and other pollutants
Model to predict risks at human environmental levels H+	Uncertainty of biological responses such as cell proliferation	Some uncertainty of biological responses such as cell proliferation
Applicability to the human process H++	Much uncertainty in pharmacokinetics and pharmacodynamics	No uncertainty
Consistency of results 0	Consistent with other rat results	Consistent with other human results
Accounting for heterogeneity of human population H+	Uncertainty in ability of the rat model to protect sensitive humans	The railroad study considered only white male workers, who may not be most sensitive
OVERALL CONCLUSION H+	Data quality is strong, but applicability to humans at environmental concentrations is uncertain	Exposure data are weak, but unlikely to greatly overstate or understate risks

[a] Symbols: H for human, A for animal, 0 for neither has the advantage. + and ++ represent the strength of the advantage.

[b] Mauderly *et al*. (1987a), Brightwell *et al*. (1989), Heinrich *et al*. (1995), Ishinishi *et al*. (1986a), Nikula *et al*. (1995)

[c] Garshick *et al*. (1988), Garshick *et al*. (1987a)

The presence or absence of a dose-response threshold is another source of uncertainty. The in vitro and in vivo genotoxicity of diesel exhaust suggests that a non-threshold mechanism for carcinogenesis may be involved. The Moolgavkar quantitative analyses of the rat cancer bioassay did not suggest there was a threshold for the carcinogenicity of diesel exhaust in the rat. In addition, as discussed in the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Appendix III, Part B, Health Risk Assessment for Diesel Exhaust, epidemiological studies have observed increases in the relative risk for lung cancer in association with exposures of the general population to ambient particulate matter. On the other hand, evidence that diesel exhaust particulate matter at high concentrations exceeds pulmonary clearance capabilities and causes chronic inflammation so as to increase production of inflammatory cytokines and cell proliferation may suggest the presence of a threshold. However, at present, the limited evidence available does not allow a threshold value for carcinogenesis to be identified.

On balance, the human data lend more confidence in the prediction of human risks than the data from the rat studies because of the uncertainties of extrapolating from rats to humans, especially in the context of a substantial particle effect. The uncertainties of extrapolating from rats to humans appear to outweigh the uncertainties of using the epidemiological results, namely, the uncertainties of the actual exposure history, modeling, and data selection. The exposure reconstructions bracket the overall exposure and therefore they bracket the risk. The uncertainty in the extrapolation from animal data is difficult to quantify, but is likely to be much greater. Extrapolations of either the animal or human data involve additional sources of uncertainty with respect to both model and data selection.

A number of individuals and organizations have indicated that the epidemiological studies are limited in their application to environmental risk assessment. OEHHA recognizes that the limited exposure information available does contribute to the overall uncertainty of the dose response risk assessment for diesel exhaust based upon the epidemiological findings. However, the overall magnitude of the associated uncertainty is not unduly large. The greater than unusual uncertainty in the exposure estimates is substantially offset by the much smaller than usual range of extrapolation from the occupational exposures of interest to the ambient levels of concern here. The availability of human data obviates the need to use animal data thus avoiding uncertainties of animal-to-human extrapolation. OEHHA provided a tabular range of risk so as to fairly capture the scope of the uncertainty in these analyses.

X. References

ARB, *Emission Inventory of Off-Road Large Compression-Ignited Engines (>25 hp) Using the New OFFROAD Emissions Model,* letter from Mark A. Carlock, June 14, 1999.

ARB, *Stationary Source Subcommittee, Table: Draft Emission Estimates for Stationary Engines, Excluding Agricultural Irrigation Pumps,* December 23, 1999.

Garshick E, Schenker MB, Munoz A, Segal M, Smith TJ, Woskie SR, Hammond SK, Speizer FE. A case-control study of lung cancer and diesel exhaust exposure in railroad workers. Am Rev Respir Dis 1987a;135:1242-8.

Garshick E, Schenker MB, Munoz A, Segal M, Smith TJ, Woskie SR, Hammond SK, Speizer FE. A retrospective cohort study of lung cancer and diesel exhaust exposure in railroad workers. Am Rev Respir Dis 1988;137:820-5.

Mauderly JL, Jones RK, Griffith WC, Henderson RF, McClellan RO. Diesel exhaust is a pulmonary carcinogen in rats exposed chronically by inhalation. Fundam Appl Toxicol 1987a;9:208-21.

Brightwell J, Fouillet X, Cassano-Zoppo AL, Bernstein D, Crawley F, Duchosal F, Gatz R, Perczel S, Pfeifer H. Tumors of the respiratory tract in rats and hamsters following chronic inhalation of engine exhaust emissions. J Appl Toxicol 1989;9:23-31.

Heinrich U, Fuhst R, Rittinghausen S, Creutzenberg O, Bellmann B, Koch W, Levsen K. Chronic inhalation exposure of Wistar rats and two different strains of mice to diesel engine exhaust, carbon black, and titanium dioxide. Inhal Toxicol 1995;7:533-56.

Ishinishi N, Kuwabara N, Nagase S, Suzuki T, Ishiwata S, Kohno T. Long-term inhalation studies on effects of exhaust from heavy and light duty diesel engines on F344 rats. Dev Toxicol Environ Sci 1986a;13:329-48.

Nikula KJ, Snipes MB, Barr EB, Griffith WC, Henderson RF, Mauderly JL. Comparative pulmonary toxicities and carcinogenicities of chronically inhaled diesel exhaust and carbon black in F344 rats. Fundam Appl Toxicol 1995;25:80-94.

Woskie SR, Smith TJ, Hammond SK, Schenker MB, Garshick E, Speizer FE. Estimation of the diesel exhaust exposures of railroad workers: II. National and historical exposures. Am J Ind Med 1988b;13:395-404.

U.S. EPA , *Certifcation Data for Nonroad Diesel Engines,* memorandum from Phil Carlson to Docket A-96-40*,* August 8, 1997

APPENDIX 1

Diesel Oxidation Catalyst and Catalyzed Diesel Particulate Filter
Control Technology Evaluations

Control Technology Evaluation

Item	Response
Technology:	Diesel Oxidation Catalyst
Technology Description: (How does it work?)	The technology reduces carbon monoxide (CO), hydrocarbons (HC), and the soluble organic fraction (SOF) of diesel particulate matter through catalytic oxidation. In the presence of a catalyst material and oxygen, CO, HC, & SOF undergo a chemical reaction and are converted into carbon dioxide and water. Some manufacturers integrate hydrocarbon traps (zeolites) and sulfate suppressants into their oxidation catalysts. Hydrocarbon traps enhance HC reduction efficiency at lower exhaust temperatures and sulfate suppressants minimize the generation of sulfates at higher exhaust temperatures.
Applicability: (What types of engines can the product be installed on?)	The technology is available for stationary and portable diesel engines between four horsepower and 5,000 horsepower and can be retrofitted to existing equipment.
Achieved Emission Reductions: (Summarize emission test results and describe in detail on the attached table.)	**Product** / **Test Cycle** / **PM Reduction** CEP Dieselytic SX / 5-Mode Steady State / 21% Nett D-Series / 8-Mode Steady State / 16% Engelhard PTX / Special Transient / 24% Engelhard CMX / FTP Transient / 30%
Emission Reduction Guarantee:	The emission reduction efficiency of this technology depends on the associated engine's baseline emissions, fuel sulfur content and emission test method / cycle. As such, oxidation catalyst manufacturers do not provide emission reduction guarantees.
Certifications: (Identify certifications the technology has received, and explain any limits on the certifications.)	Several models have been certified under EPA's Urban Bus Retrofit/Rebuild program.
Product Costs: Initial Retail:	Costs in parenthesis are costs of applicable new engines and gen-sets. The initial cost range of DOCs is: $400 - $550 for a 40 hp engine (cost of engine: $7,000-$8,000; gen-set: $18,000-$23,000); $680 - $1,356 for a 100 hp engine (engine: $8,000-$11,000, gen-set $29,000) ; $2,100 - $2,600 for a 275 hp engine (engine: $13,000-$30,000;gen-set $45,000); $3,400 - $3,700 for a 400 hp engine (engine: $22,000-$34,000; gen-set: 73,000); and $14,000 - $20,000 for a 1400 hp engine (engine: $95,000-$135,000; gen-set: $210,000-$325,000).
Installation:	Approx. $167 (Assuming 1.5 hours x $78/hr + $50 in misc parts.)
Operating:	None
Maintenance:	$64/year - $712/year (Assumes $50 - $100 for thermal cleaning and 1 hour labor (at $78/hour): once every other year to 4 times per year, depending on manufacturer recommendations and application).

Item	Response
Technology:	Diesel Oxidation Catalyst
Comments:	The technology requires periodic maintenance which may include thermal cleaning. The frequency of the maintenance depends on the manufacturer and application and varies from biennially to four times per year. The maintenance costs above reflect this schedule.
Durability: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Manufacturers claim that the useful life of the technology depends on the application, and that it varies between 4,000 and 10,000 service hours. However, the useful life generally appears to be consistent with the rebuild cycle of the associated engine: one manufacturer recommends replacing the catalyst at the time an engine is rebuilt. Another manufacturer claims that their product's useful life can extend to 25,000 service hours, but this depends on the condition of the engine, type of fuel and maintenance practices.
Product Warranty: (Identify the type of warranty and its duration.)	Diesel oxidation catalysts typically carry a 2,000 service hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	The technology imposes additional exhaust gas flow restrictions of between 4 - 11 inches of water column; however, the additional restriction is expected to be within the manufacturer's specifications. As such, the technology is not expected to have an impact on an OEM engine warranty.
Adverse Impacts: **Environmental:**	As is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g., ultra-low sulfur fuel or minimum exhaust temperature, etc...)	One manufacturer recommends cleaning their product every 6 months or 2,000 service hours (whichever occurs first) when it is installed on newer engines, and every 3 months or 1,000 service hours (whichever occurs first) when it is installed on older engines. The catalyst can be cleaned by the engine operator by either: 1) applying a compressed air stream to the face of the catalyst; 2) heat treating the catalyst core; or 3) soaking the catalyst in an appropriate solvent.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available and has been installed on tens of thousands of mobile diesel engines. Manufacturers claim that this technology has also been applied to both stationary and portable diesel engines; however, ARB staff have not identified any specific stationary or portable applications.

Item	Response
Technology:	Diesel Oxidation Catalyst
Other: (e.g., fuel penalty, reduced product life, weight, affect on engine performance, etc...)	
Impacts of Lower Sulfur Diesel Fuel	Use of diesel fuel with a very low sulfur content will improve the technology's particulate reduction efficiency.
Comments: (Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)	In addition to reducing the SOF of diesel particulate matter, the product also reduces carbon monoxide and hydrocarbon emissions.

List of Stationary &/or Portable Applications

Technology Name: Diesel Oxidation Catalyst

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
No known stationary or portable applications of this technology.	Make: Model: Application: Fuel Type:					

List of Emission Test Results

Technology Name: Diesel Oxidation Catalyst

Method & Type of Test	Source Test Company	Product Information	Engine Information	Baseline PM Emission Rate	PM Emission Rate w/ Controls	Control Efficiency
8-mode steady-state	Canada Center for Mining and Minerals Technology July 1998	Dieselytic SX Exhaust Gas Purifier Mfg. By: Catalytic Exhaust Products Limited	Make: Deutz Model: F6L-912W Year: 1979 BHP: 75.4 bhp Application: Underground mining Configuration: Naturally aspirated Engine Hours: Approx. 2,000 hours Fuel Type: 250 ppm Sulfur Diesel Fuel Use: 31.9 lb/hr Exhaust Temp: 146°F - 880°F	100.6 mg/m^3 (0.617 g/bhp-hr)[4]	84.9 mg/m^3 (0.516 g/bhp-hr)[1]	16%
ISO 8178-D2 5-mode steady-state	Not Publicly Available[5]	Nett DH422 Diesel Purifier Mfg. By: Nett Technologies	Make: Ford Model: 5.0 liter Year: Unknown BHP: 150 Application: Generator Configuration: Unknown Engine Hours: Unknown Fuel Type: Diesel Fuel Use: Unknown Exhaust Temp: 933°F	0.5656 g/bhp-hr	0.4475 g/bhp-hr	21%

[4] Value calculated by ARB staff using EPA Method 19 calculation procedures.

[5] The manufacturer has requested that the name of the company that performed the emission tests be withheld from publication.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Baseline PM Emission Rate	PM Emission Rate w/ Controls	Control Efficiency
ISO 8178-D2 5-mode steady-state	Not Publicly Available[6]	Nett DH312 Diesel Purifier Mfg. by: Nett Technologies, Inc.	Make: Ford Model: 5.0 liter Year: Unknown BHP: 150 Application: Generator Configuration: Unknown Engine Hours: Unknown Fuel Use: Unknown Exhaust Temp: 948°F	0.5656 g/bhp-hr	0.521 g/bhp-hr	8%

[6] The manufacturer has requested that the name of the company that performed the emission tests be withheld from publication.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Baseline PM Emission Rate	PM Emission Rate w/ Controls	Control Efficiency
Transient cycle designed for a specific bulldozer application.	Emissions Research and Measurement Division, Environment Canada[7]	PTX Oxidation Catalyst Mfg. by: Engelhard Corporation	Make: Cummins Model: TD-25G Year: Unknown BHP: 450 Application: Bulldozer Configuration: Unknown Engine Hours: Unknown Fuel Type: 530 ppm S Diesel Fuel Use: 34.36 kg/hr Exhaust Temp: Unknown	62.54 g/hr	47.40 g/hr	24%

[7] Study reported in SAE Technical Paper # 1999-01-0110 entitled "The Impact of Retrofit Exhaust Control Technologies on Emissions from Heavy-Duty Diesel Construction Equipment."

Method & Type of Test	Source Test Company	Product Information	Engine Information	Baseline PM Emission Rate	PM Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure	Unknown[8]	CMX Diesel Oxidation Catalyst Mfg. by: Engelhard Corporation	Make: Cummins Model: L-10 Year: 1992 BHP: 280 Application: Urban Bus Configuration: Electronic Controls Engine Hours: Unknown Fuel Type: Diesel with maximum sulfur content of 500 ppm Fuel Use: Unknown Exhaust Temp: Unknown	0.105 g/bhp-hr	0.073 g/bhp-hr	30%

[8] Emission test information submitted to US EPA as part of Engelhard Corporation's application for certification under the Urban Bus Retrofit/Rebuild program. The name of the emission test company was not referenced in the Federal Register Document (FRL-5984-3).

Item	Response
Technology:	Catalyzed Diesel Particulate Filter
Technology Description: (How does it work?)	The technology is a passive, self-regenerating catalyzed diesel particulate filter (C-DPF). The technology reduces particulate matter, carbon monoxide, and hydrocarbon emissions through catalytic oxidation and filtration. The C-DPF collects diesel particulate matter and oxidizes it during hot duty cycle operations. (This process of cleaning the C-DPF is called regeneration.) Typically, the filter media consists of ceramic wall-flow monoliths which capture the diesel particulates. These ceramic monoliths are either coated with a catalyst material or a separate catalyst is installed upstream of the C-DPF. The catalyst reduces the temperature at which the collected particulate matter oxidizes, and it oxidizes the soluble organic, carbon monoxide and hydrocarbon emissions.
Applicability: (What types of engines can the product be installed on?)	The technology is available for stationary and portable diesel engines rated at 5,000 horsepower or less and can be retrofitted to existing equipment. However, the technology is not appropriate for an application where an engine and its associated duty cycle do not generate enough heat to oxidize the collected particulate matter and regenerate the filter. For example, C-DPFs may not be appropriate for engines used in severe cyclic operations.
Achieved Emission Reductions:	**Product** / **Test Cycle** / **PM Reduction** Nett SF Soot Filter / CBD Transient / 92% Engelhard DPX / Special Transient / 97% CleanDiesel Soot Filter / ISO 8178 C1 / 85%
Emission Reduction Guarantee:	The emission reduction efficiency of this technology depends on the associated engine's baseline emissions, fuel sulfur content, and emission test method / cycle. As such, DPF manufacturers do not provide emission reduction guarantees.
Costs: Initial Retail:	According to one manufacturer, the range in initial cost is: $3300 for a 40 hp (cost of engine: $7,000-$8,000; gen-set: $18,000-$23,000); $5000 for a 100 hp engine (engine: $8000-$11,000; gen-set: $23,000); $6900 for a 275 hp engine (engine: $13,000-$30,000: gen-set: $45,000); $10,500 for a 400 hp engine (engine: $22,000-$34,000; gen-set: $56,000); and $44,000 for a 1,400 hp engine (engine: $95,000-$135,000;genset:$210,000-$325,000).
Installation:	$167 - $518 (Assuming 1.5 - 6 hours x $78/hr + $50 in misc parts.)
Operating:	Fuel consumption may increase by one to one and a half percent due to additional backpressure.
Maintenance:	$156 - $312 (Assuming 2 - 4 hours labor per year.)
Comments:	DPFs should be cleaned regularly. Because of their higher backpressures (e.g. 20 - 40 in. wc.) and the potential for masking by lube oil ash, ARB staff expect that the periodic maintenance of DPFs will be more frequent and possibly more extensive than that of diesel oxidation catalysts. ARB staff expect that the maintenance costs listed above reflect the minimum.

Item	Response
Technology:	Catalyzed Diesel Particulate Filter
Certifications:	
Durability: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Manufacturers claim that the useful life of the technology can be as high as 8,000 to 12,000 service hours if properly maintained. However, this may be reduced when a C-DPF is installed on poorly maintained engines with leaking fuel injectors, a dirty intake air cleaner, excessive oil consumption, and/or lubricating oil in the exhaust. In addition, particulate matter can build up on a C-DPF when an engine does not achieve the proper regeneration temperature for the proper duration (i.e., soot overloading). With this build up, if the C-DPF subsequently begins to regenerate, the collected particulate can oxidize uncontrollably and destroy the particulate filter.
Warranty:	DPFs typically carry a 2,000 service hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	The technology imposes additional exhaust flow restrictions of between 20" to 40" of water column or more. In some applications, such as severe cyclic operations, the engine may not generate enough heat to oxidize the collected particulate matter and regenerate the filter. This can lead to soot overloading and backpressures beyond the manufacturer's recommended limit. The specific impact on an OEM engine warranty is not known.
Adverse Impacts: **Environmental:**	No known adverse environmental impacts.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g., ultra-low sulfur fuel or minimum exhaust temperature, etc...)	As is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset a portion of the C-DPF's particulate reductions. In addition, sulfur dioxide can counteract the effect of the catalyst material and increase the C-DPF's regeneration temperature. Diesel fuel with a very low sulfur content will maximize the emission reduction capability of this technology.
	C-DPFs must be selected for the specific engine and its associated duty cycle. All engines must be able to maintain the minimum regeneration temperature (which varies by product) for at least 20% of the engine's duty cycle.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available and has been installed on several thousand mobile diesel engines. The product has also been installed on a few stationary diesel engines.

Item	Response
Technology:	Catalyzed Diesel Particulate Filter
Other: (e.g., fuel penalty, reduced product life, weight, affect on engine performance, etc...)	A fuel penalty of up to 1 - 1½% may be incurred due to the increased backpressure.
Impacts of Lower Sulfur Diesel Fuel	Use of diesel fuel with a very low sulfur content will improve the technology's particulate reduction efficiency.
Comments: (Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)	In addition to reducing particulate emissions, the product also reduces carbon monoxide and hydrocarbon emissions.

List of Stationary &/or Portable Applications

Technology Name: Diesel Particulate Filter

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Sierra Nevada Brewing Company, Inc. Chico, CA	Make: Caterpillar Model: 3412 Application: Generator Fuel Type: Shell Amber 363	Authority to Construct No. SNB-99-09-AC Issued by Butte County AQMD	Two C-DPFs installed on each of two emergency backup generators.	Recent Installation	0.0584 lb/hr	Emission testing scheduled for January 2000

List of Emission Test Results

Technology Name: Diesel Particulate Filter

Method & Type of Test	Source Test Company	Product Information	Engine Information	Baseline PM Emission Rate	PM Emission Rate w/ Controls	Control Efficiency
Central Business District (CBD) - Heavy Duty Chassis Dynamometer Emission Test	Environment Canada, Emission Research and Measurement Division, Report #97-26771-3 (Unpublished)	Nett SF Soot Filter Mfg. by Nett Technologies	Make: Navistar Model: T444 Diesel-Electric Year: Not known BHP: Not known Application: Hybrid Diesel-Electric Transit Bus Configuration: Not known Engine Hours: Not known Fuel Type: Certification Diesel D2 Fuel Use: Not known Exhaust Temp: Not known	w/ oxidation catalyst - 0.318 g/mile	600 rpm Config. - 0.036 g/mile 750 rpm Config. 0.027 g/mile	92% 89%
Special transient cycle designed for a specific wheel loader application.	Emissions Research and Measurement Division, Environment Canada[9]	DPX Particulate Filter Mfg. by Engelhard Corporation	Make: Caterpillar Model: 988 Year: Unknown BHP: 320 Application: Wheel loader Configuration: Unknown Engine Hours: Unknown Fuel Type: 530 ppm S Diesel Fuel Use: 15.8 kg/hr Exhaust Temp: Unknown	17.38 g/hr	0.59 g/hr	97%

[9] Study reported in SAE Technical Paper #1999-01-0110 entitled "The Impact of Retrofit Exhaust Control Technologies on Emissions from heavy-Duty Diesel Construction Equipment."

Method & Type of Test	Source Test Company	Product Information	Engine Information	Baseline PM Emission Rate	PM Emission Rate w/ Controls	Control Efficiency
ISO 8178 C1	AB Svensk Motor Test Center	CleanDiesel Soot Filter Mfg. by Clean Air Systems	Make: Volvo Model: TD61-G Year: Unknown BHP: Unknown Application: Mobile Source Configuration: Unknown Engine Hours: Unknown Fuel Type: 50 ppm S MK-1 Diesel Fuel Use: Unknown Exhaust Temp: Unknown	0.142 g/bhp-hr	0.022 g/bhp-hr	85%

APPENDIX 2

Potential Cancer Risk Associated
with the Air Dispersion Modeling Results

Air Resources Board staff used the U.S. EPA's Industrial Source Complex-Short Term (ISCST3) air dispersion model to estimate the annual average concentration of particulate matter (PM) emitted from standby stationary diesel-fueled engines of different horsepower ratings. This Appendix identifies the potential cancer risk associated with being exposed to those annual average concentrations. Section I identifies the air dispersion modeling assumptions and inputs. Section II is a series of graphs that illustrate the risk associated with the annual average concentrations of PM.

I. MODELING ASSUMPTIONS AND INPUTS

A. Horsepower ratings: The model estimated the PM emissions from diesel-fueled engines with the following horsepower ratings: 100, 200, 300, 400, 500, 750, 1000, and 1400.
B. Annual hours of operation: Each standby engine operates 50 hours per year for routine maintenance or testing to ensure it is operating properly.
C. Testing or maintenance of standby engines typically occurs during the daytime (i.e., 6 a.m. to 6 p.m.).
D. The hour of the day that presents the highest concentration of PM emissions, and the worst – case meteorological conditions, occurs somewhere between 6 a.m. and 6 p.m.
E. See Section D. Meteorological Data for the determination of when this "hour of day" occurs.
F. Load factor is equal to 100%.
G. Modeling Inputs:

1. Stack velocity (VS):

ENGINE HORSEPOWER	STACK VELOCITY (VS) (METERS/SECOND)
100	53.2
200	59.8
300	57.4
400	76.6
500	66.5
750	73.3
1000	59.1
1400	46.5

VS was calculated as follows:

VS = (Actual exhaust cubic feet per minute (acfm) x (1/stack cross-sectional area)

$$\text{Acfm} = \frac{(\text{dscfm})(\text{exhaust temp})}{(\text{ambient temp})(1-[\%\text{ moisture by vol}])}$$

Dscfm (dry standard exhaust cubic feet per minute) calculated using U.S. EPA Method 19 “F” factors (An “F” factor is the ratio of combustion gas volumes to heat inputs.)
Where:

Dscfm = (fuel use)(“F“ factor)(O_2 correction)(load)(diesel heat content)
Fuel use (gal/hr) = (7100 btu/bhp-hr)(1 gal/137,000btu)(hp)
“F” factor = 9190 dscf/1,000,000 btu
O_2 correction = 20.9/(20.9-10.8)
Load = 100%
Diesel heat content =137,000 btu/gal
Exhaust temperature = 622 K
% moisture by volume = 7.10%

2. Emission factor (g/s) = (hp rating)(0.1 grams of PM/bhp-hour)(1hr/3600 sec)
(Q/S) = 0.00278 g/s

3. Stack height (HS): 3.0 meters

4. Stack temperature (TS): 622 K

5. Stack diameter (DS)

ENGINE HORSEPOWER	STACK DIAMETER (DS) (METERS)
100	0.076
200	0.102
300	0.127
400	0.127
500	0.152
750	0.178
1000	0.229
1400	0.305

Note: interpolated from known engine configurations

6. Setting: Urban

H. Meteorological Data: Offsite representative meteorological data from Anaheim (1981) and West Los Angeles (1981) was used. The worst case hour is the hour of the day that would result in the highest modeled concentrations of PM. The worst case hour was determined as follows: [Note: The values for TS, VS, and DS identified below were preliminary estimates for a 100 hp engine. These values differ from the modeling inputs used in estimating the annual average concentration of PM emitted from a 100 hp engine, as identified in Section C. We are in the processes of updating the worst case hour analysis to include the modeling inputs discussed in Section C. We expect the updated analysis to show the worst case hour is 3:00 p.m.]

1. The worst case hour was assumed to occur between 6 a.m. and 6 p.m. because the engines are standby engines and they only operate during the day.

2. The ISCST3 model was run for a100-hp engine emitting during the hours of 6 a.m. and 12 noon:

3. Modeling inputs are as follows:
   - QS = 0.00278 g/sec
   - HS = 3.0 meters
   - TS = 622^0K
   - VS = 53.2 m/sec
   - DS = 0.076 meters

4. The ISCST3 model was run for the 100-hp engine emitting from 1 p.m. to 6 p.m.

5. The highest annual average concentration value was in the afternoon hours.

6. Next, each afternoon hour was run individually. For example, the ISCST3 model was run for the 100-hp engine emitting at 1 p.m. This was repeated for the 2 p.m. hour, the 3 p.m. hour, the 4 p.m. hour, the 5 p.m. hour, and finally the 6 p.m. hour.

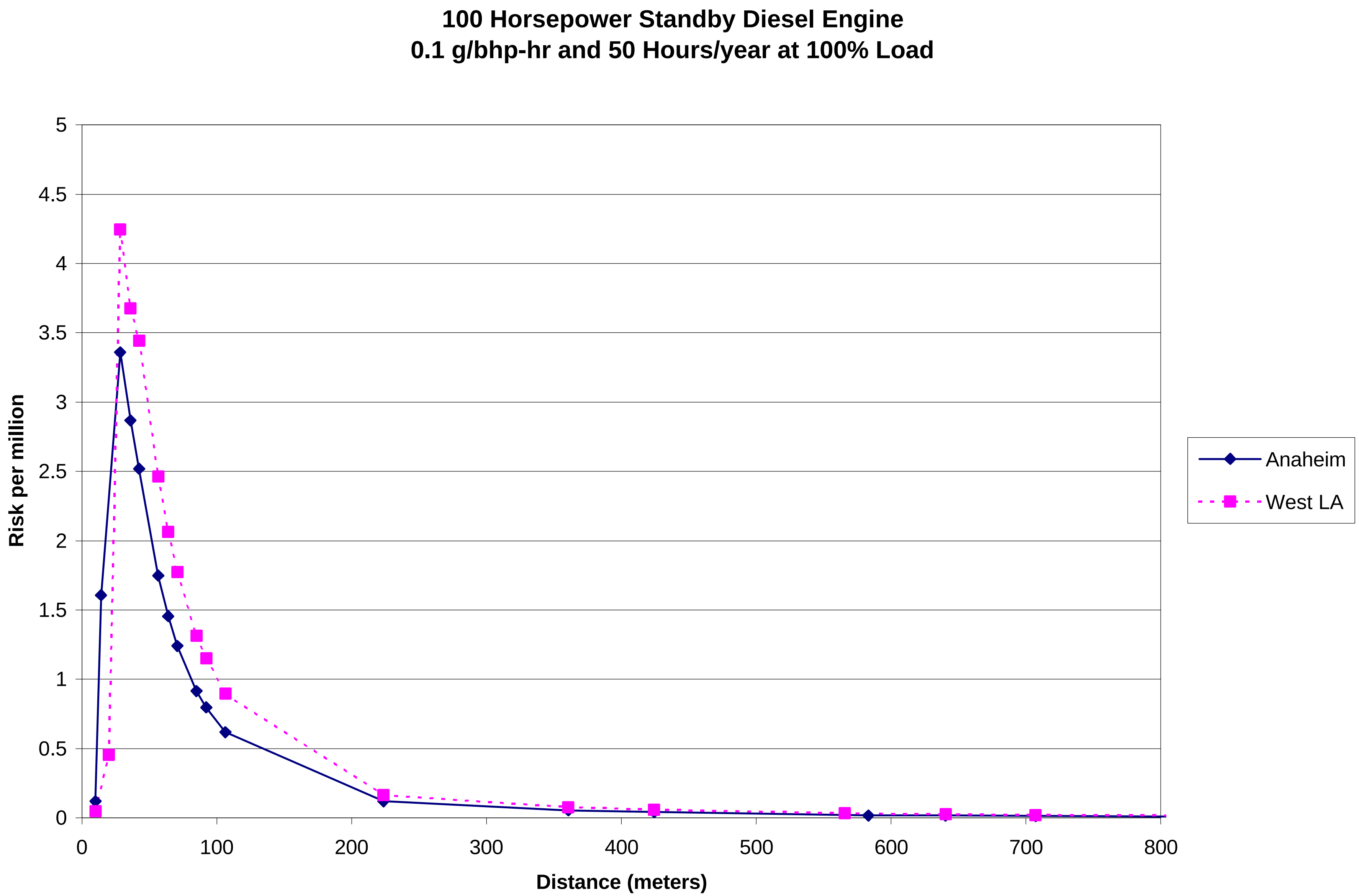
7. This procedure was completed for both the Anaheim meteorology and the West Los Angeles (LA) meteorology.

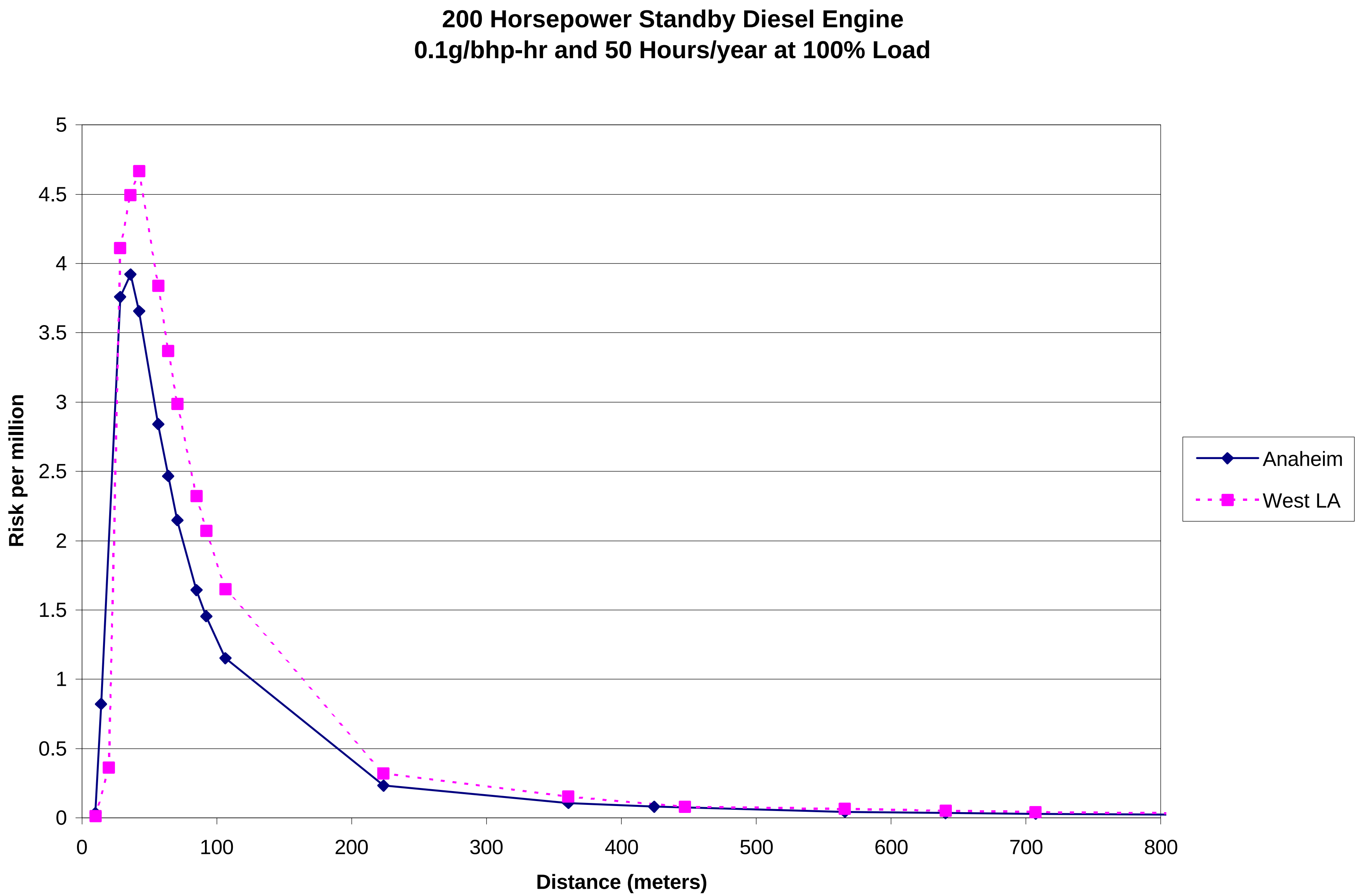
8. The highest annual average concentration value was at the 3 p.m. hour. Therefore, the worst case hour for both the Anaheim and the West LA meteorology data is considered to be the 3 p.m. hour.

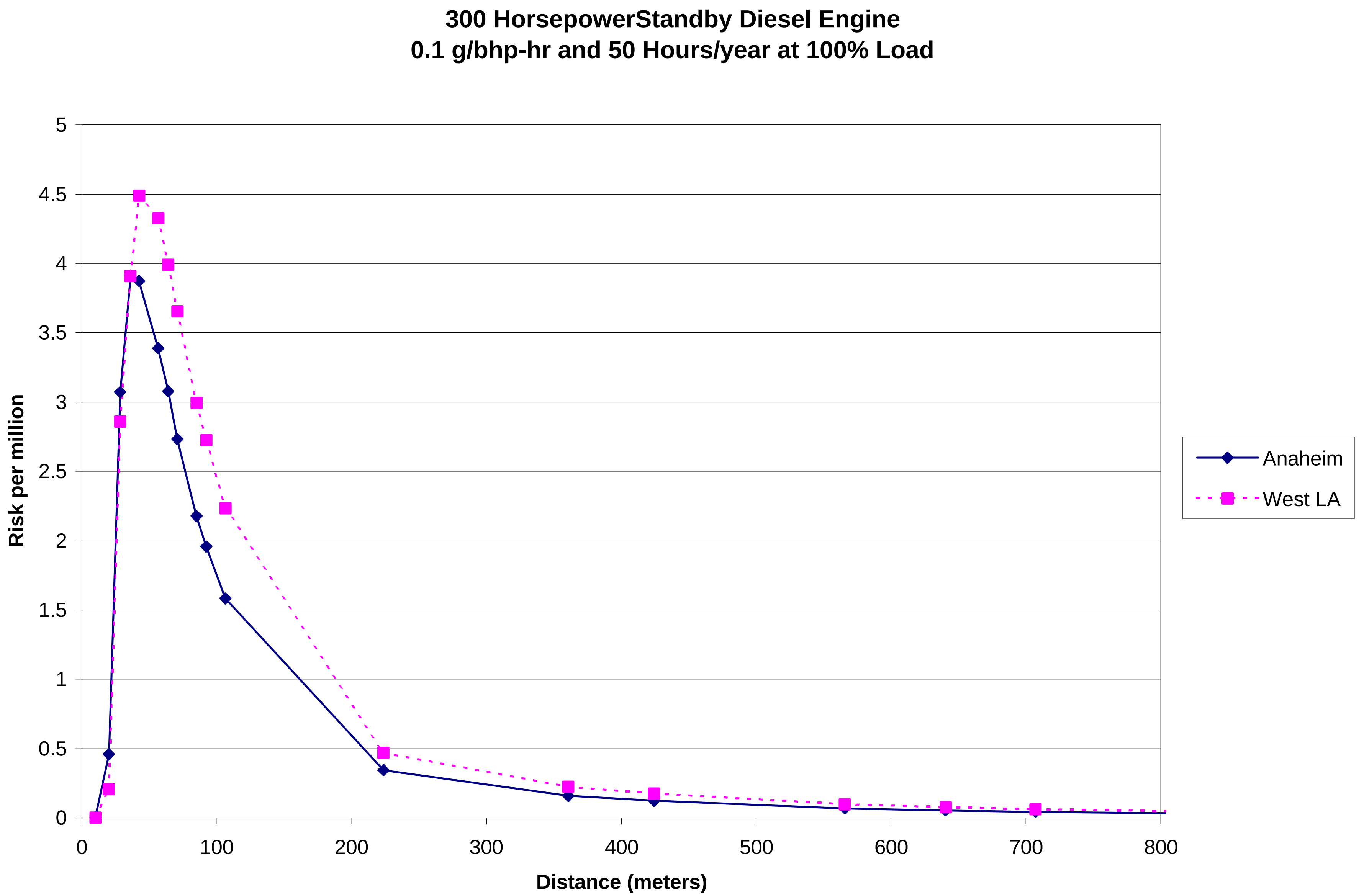
9. The fraction of each hour (duration) during which PM emissions occurred was set to be 0.137. (50 emission days/year / 365 days/year = 0.137).

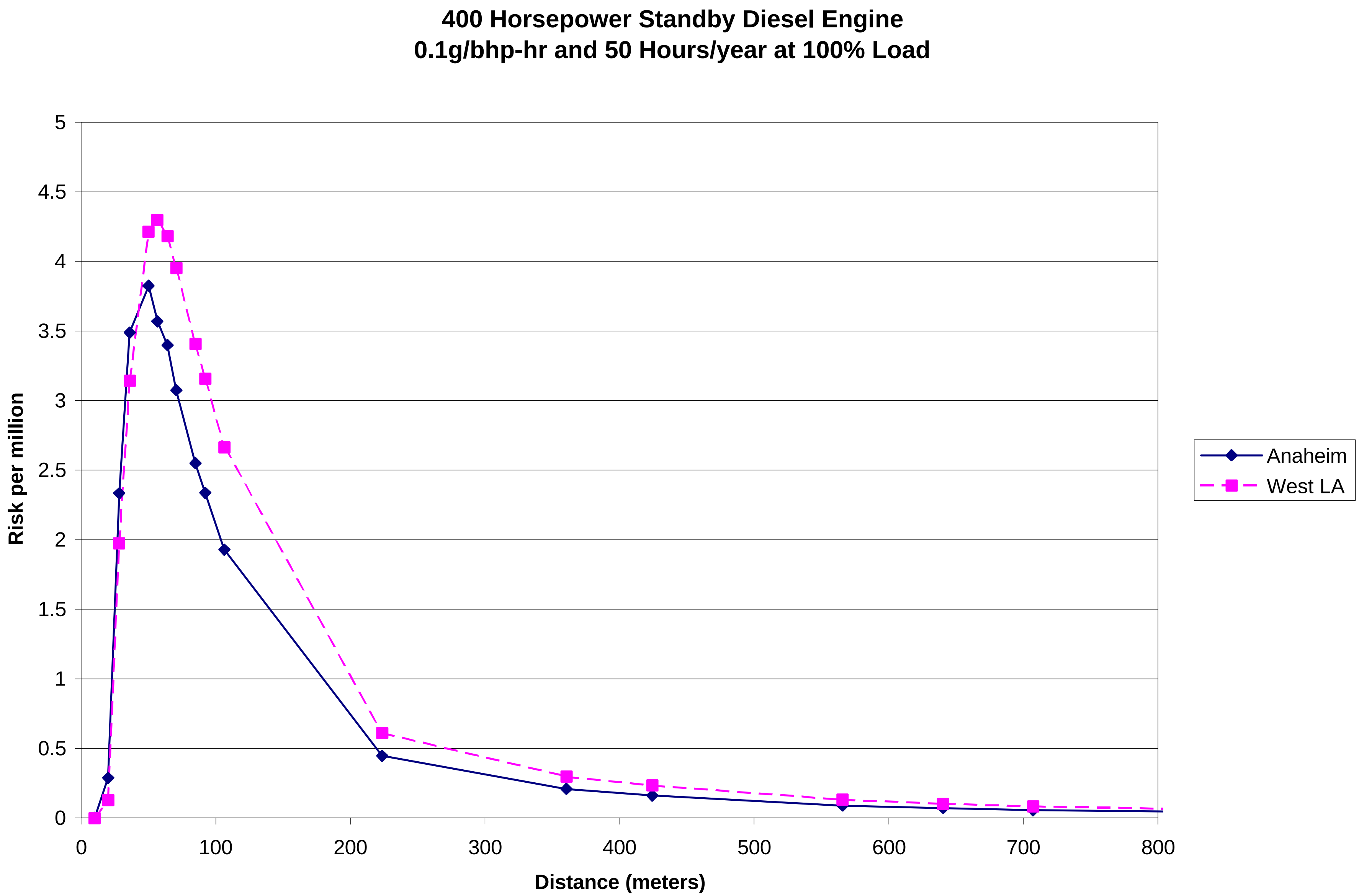
II. RISK CALCULATIONS

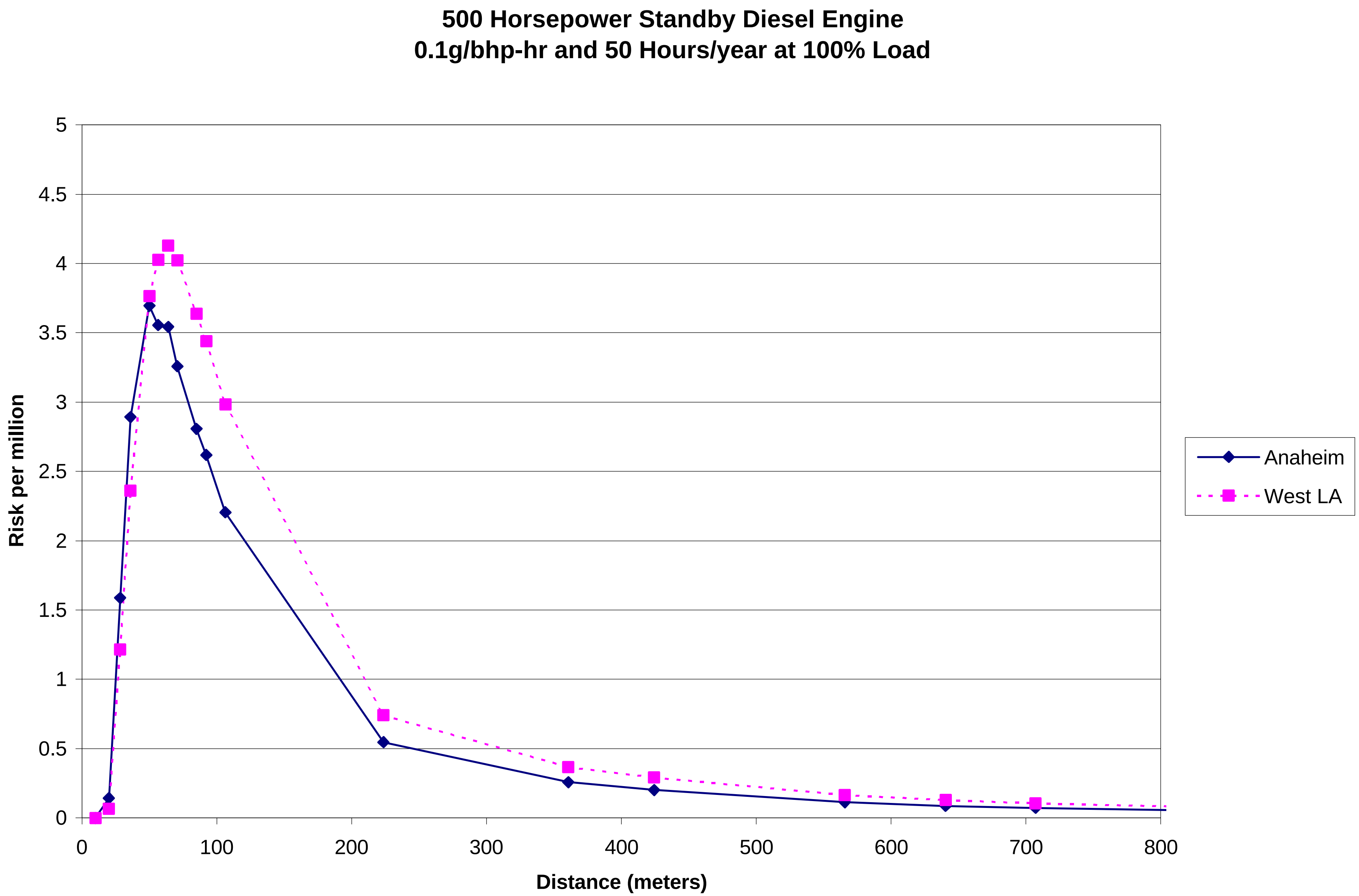
The ISCST3 air dispersion model was used to estimate the annual average concentration ($\mu g/m^3$). The potential cancer risk to nearby receptors was estimated by multiplying the annual average concentration by the reasonable unit risk factor (URF) for diesel particular matter, 300×10^{-6} $(\mu g/m^3)^{-1}$. The following eight graphs show the cancer risk at several receptor distances for the eight different horsepower engines modeled.

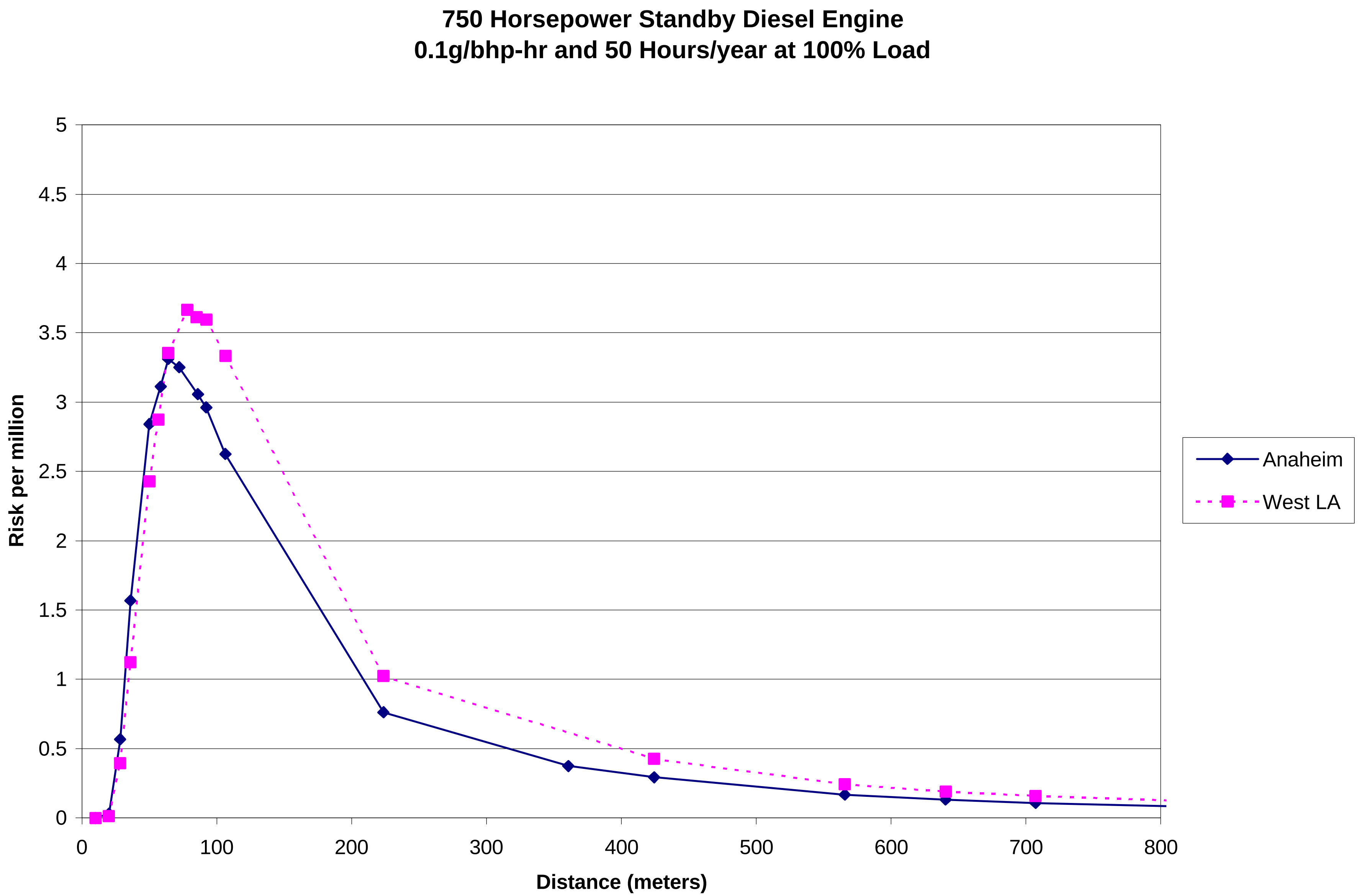

100 Horsepower Standby Diesel Engine
0.1 g/bhp-hr and 50 Hours/year at 100% Load
Risk per million
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
100
200
300
400
500
600
700
800
Distance (meters)
Anaheim
West LA

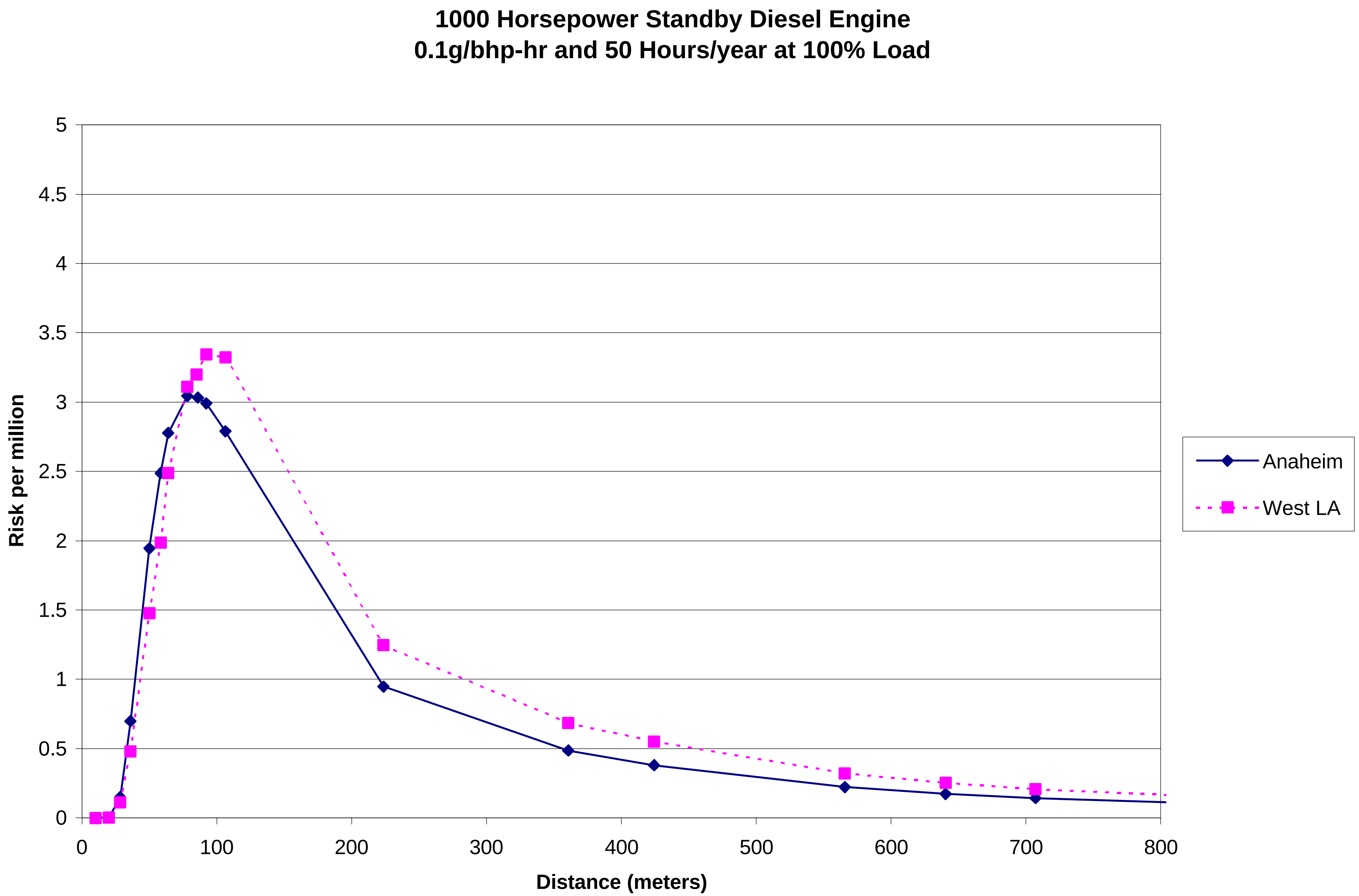

200 Horsepower Standby Diesel Engine
0.1g/bhp-hr and 50 Hours/year at 100% Load
Risk per million
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
100
200
300
400
500
600
700
800
Distance (meters)
Anaheim
West LA

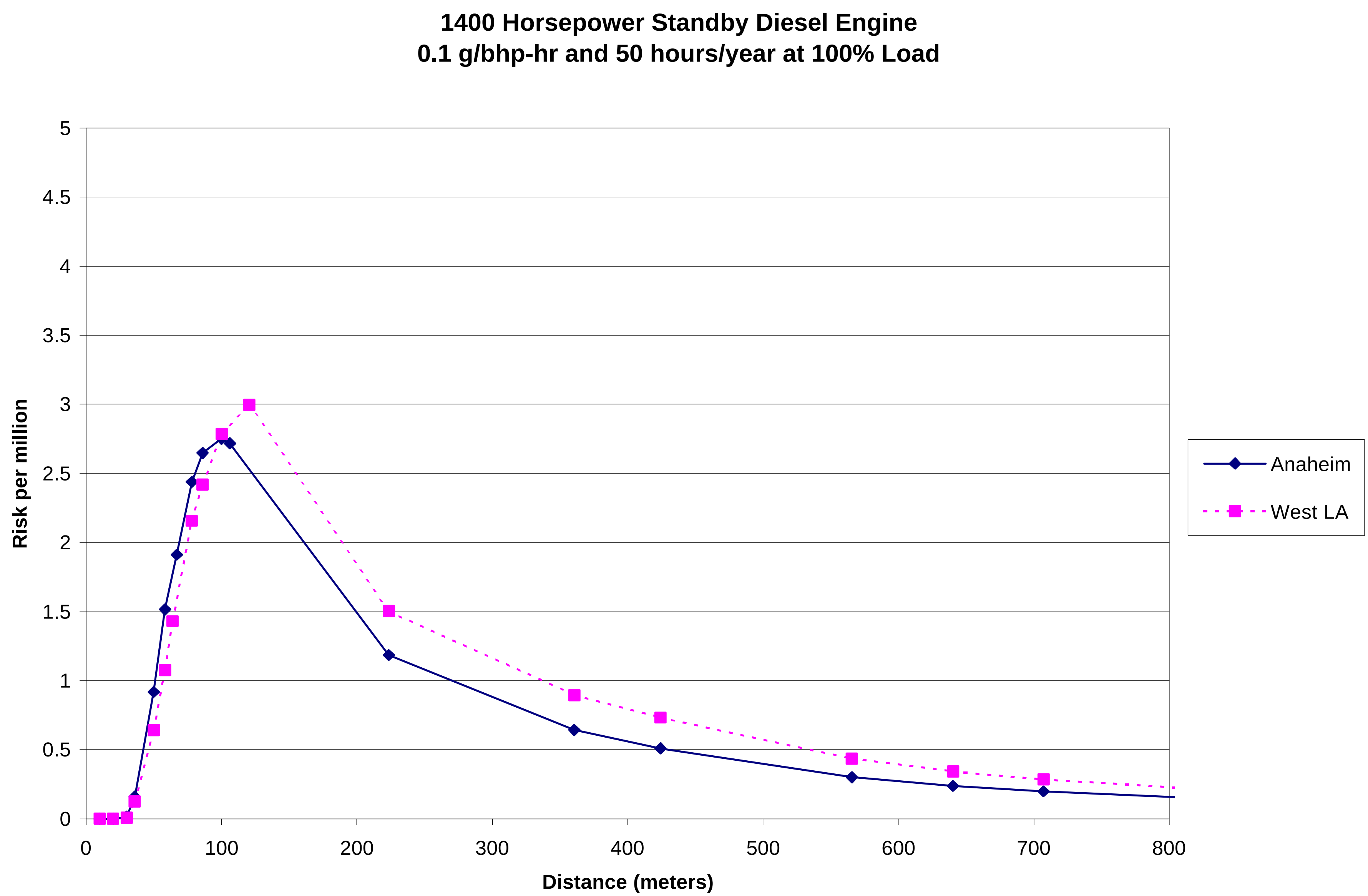

300 HorsepowerStandby Diesel Engine
0.1 g/bhp-hr and 50 Hours/year at 100% Load
Risk per million
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
100
200
300
400
500
600
700
800
Distance (meters)
Anaheim
West LA


400 Horsepower Standby Diesel Engine
0.1g/bhp-hr and 50 Hours/year at 100% Load
Risk per million
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
100
200
300
400
500
600
700
800
Distance (meters)
Anaheim
West LA


500 Horsepower Standby Diesel Engine
0.1g/bhp-hr and 50 Hours/year at 100% Load
Risk per million
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
700
800
Distance (meters)
Anaheim
West LA


750 Horsepower Standby Diesel Engine
0.1g/bhp-hr and 50 Hours/year at 100% Load
Risk per million
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
100
200
300
400
500
600
700
800
Distance (meters)
Anaheim
West LA


1000 Horsepower Standby Diesel Engine
0.1g/bhp-hr and 50 Hours/year at 100% Load
Risk per million
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
100
200
300
400
500
600
700
800
Distance (meters)
Anaheim
West LA


1400 Horsepower Standby Diesel Engine
0.1 g/bhp-hr and 50 hours/year at 100% Load
Risk per million
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
100
200
300
400
500
600
700
800
Distance (meters)
Anaheim
West LA

APPENDIX 3

Draft Sierra Nevada Brewery Source Test Protocol

Sierra Nevada Brewery Source Test Protocol

Purpose

- Determine the emission of particulate emissions, NO_x, CO, HC, and SO_2 from two 1100 horsepower diesel-fired engines

- Ensure that the emissions meet district permit conditions

- Evaluate the effectiveness of add-on control equipment applied to two 1100 horsepower diesel-fired engines by determining the particulate matter concentration output before and after add-on controls with Method 5.

- Evaluate the change in particulate emissions from using SHELL AMBER 363 vs. CARB DIESEL at load

- Evaluate the change in particulate emissions from operating at a weekly level (1 hour /week, no load, 1800 RPMs) vs. operating continuously (with maximum load - facility may rent load bank to simulate load - 1800 RPMs) on CARB Diesel

- Measure sulfur level and other parameters of fuel (SHELL AMBER 363 and CARB DIESEL)

Quality Assurance Objectives

Accuracy – include data quality objectives for calibrations, method detection limits, and quality assurance samples

Precision – provide for duplicate analytical samples

Completeness – plan two runs of each test method

Representativeness

- sample at ports away from flow disturbances, sample from a sufficient number of sample points at defined positions across stack traverses, and check that flow is parallel to sample nozzles

- collect sample during normal source operation and collect over as long a period as practical to include any normal variation in operation

DRAFT

Summary of Proposed Emissions Testing For
1100 Horsepower Diesel Generators At Sierra Nevada Brewery

	Fuel	Operation	Before or After Control	Test Method	Engine	# of Samples
Particulate Emission Source Test for Continuous (load) Operation for Engine #1 And CO, O_2, NO_x, and HC Determination (Remember to take fuel sample to test sulfur content and aromatic HC)						
1.	SHELL AMBER 363	(load)	Before	ARB Method 5 and Method 100 *	#1	2
2.	SHELL AMBER 363	(load)	After Catalyst # 1	ARB Method 5 and Method 100	#1	2
3.	SHELL AMBER 363	(load)	After Catalyst # 2	ARB Method 5 and Method 100	#1	2
Perform Method 5 and Method 100 for both catalysts (2 outlets).						
Particulate Emission Source Test for Continuous (load) Operation for Engine #2 And CO, O_2, NO_x, and HC Determination						
4.	SHELL AMBER 363	(load)	Before	ARB Method 5 and Method 100 *	#2	2
5.	SHELL AMBER 363	(load)	After Catalyst #1	ARB Method 5 and Method 100	#2	2
6.	SHELL AMBER 363	(load)	After Catalyst #2	ARB Method 5 and Method 100	#2	2
Perform Method 5 and Method 100 both catalysts (2 outlets).						
Comparison of CARB DIESEL to Shell Amber 363 Particulate Emissions at Load And comparison of no load to load on CARB Diesel And CO, O_2, NO_x, and HC Determination (Remember to take fuel sample to test sulfur content and aromatic HC)						
7.	CARB DIESEL	(no load)	Before	ARB Method 5 and Method 100 *	#1	2
8.	CARB DIESEL	(no load)	After Catalyst #1	ARB Method 5 and Method 100	#1	2
9.	CARB DIESEL	(no load)	After Catalyst #2	ARB Method 5 and Method 100	#1	2
Perform Method 5 and Method 100 for both catalysts (2 outlets).						
10.	CARB DIESEL	(load)	Before	ARB Method 5 and Method 100 *	#1	2
11.	CARB DIESEL	(load)	After Catalyst #1	ARB Method 5 and Method 100	#1	2
12.	CARB DIESEL	(load)	After Catalyst #2	ARB Method 5 and Method 100	#1	2
Perform Method 5 and Method 100 for both catalysts (2 outlets).						

***** Measure RPM and brake-hp/hr during tests and take fuel sample for sulfur content and aromatic HC)

Additional Measurements

Measure RPM during tests
Measure brake-horse power/hour during tests
Report results in lbs/hr and g/brake-horse power/hour
Analyze each fuel for sulfur content and aromatic HC

Participants and Stakeholders

ARB
Butte County Air Quality Management District
Sierra Nevada Brewery
Caterpillar
Engelhard

Source Description

1100 horsepower Caterpillar Model 3412 DISTA diesel-fired generator
emissions rating = 0.109 gram/brake horsepower-hour of particulate emissions without control

Control Equipment

Engelhard DPX soot trap (a combination catalytic converter and soot filter)
The catalyst allows the soot to be burned at exhaust temperatures to CO_2 and H_20.
Metals collect in the catalyzed filter. Recommend cleaning by vacuuming every 1500 hours and reversing the catalyst when reinstalling.

Sampling Location

Conduct a pre-test site inspection
Conduct a velocity traverse
Verify parallel or non-cyclonic flow per ARB Method 1

Sampling Equipment

As specified in each test method
Must be calibrated and inspected for proper operation prior to use in the field

Testing Dates (Tentative)

March 2000

Sampling and Analytical Procedures

- Sample and Velocity Traverses using ARB Method 1 “Sample and Velocity Traverse for Stationary Sources”
- Stack gas velocity and volumetric flow rate using U.S. EPA Method 2A “Determination of Stack Gas Velocity and Volumetric Flow Rate”
- Moisture content using ARB Method 4 “Determination of Moisture Content in Stack Gases”
- Continuous Emissions Monitoring (CO, O_2, NO_x, HC, and SO_2) using ARB method 100 “Procedures for Continuous Gaseous Emissions Stack Sampling”
- Stack Gas Molecular Weight using ARB Method 3 “Gas Analysis for Carbon Dioxide, Oxygen, Excess Air and Dry Molecular Weight”
- Particulate Matter using ARB Method 5 “Determination of Particulate Matter Emissions from Stationary Sources”

Process Parameters

Stack height
Stack temperature
Stack exit velocity (flow rate)
Stack diameter
Inlet, outlet temperature

Building dimensions
Time of day emissions collected
Ambient air temperature
Engine horsepower
Setting (i.e. rural vs. urban)
Receptor distance
Plot plan